How Systems Work

Proceedings of Farming Systems Research Symposium 1987

University of Arkansas
Winrock International Institute for Agricultural Development

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Please address any questions and comments to Dr. Tom Westing, Director, International Agricultural Programs, 300 Hotz Hall, University of Arkansas, Fayetteville, AR 72701, U.S.A., telex 314000.

Program Committee

University of Arkansas:

Tom Westing
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ROBERT W. HERDT

Robert Herdt is Director of Agricultural Sciences at the Rockefeller Foundation. He has studied and participated in agricultural development for his entire professional career.

Herdt received his undergraduate education at Cornell University in the field of agriculture, then continued at that university to take a master's degree in agricultural economics. He received a Ph.D. from the University of Minnesota in agricultural economics in 1969.

Herdt spent two years in India with the Ford Foundation's Intensive Agricultural District Program in 1962-1964 and another two years (1967-1968) with the Indian Agricultural Research Institute as part of the Rockefeller program. He was appointed assistant professor in the Agricultural Economics Department of the University of Illinois in 1969 and was named associate professor there in 1974 while on leave. In 1973 he went to the International Rice Research Institute (IRRI) as an agricultural economist; in 1978 he became head of the Economics Department there. Upon resigning from IRRI in 1983, he became scientific advisor in the Secretariat of the Consultative Group on International Agricultural Research located at the World Bank. In 1986 he was appointed senior economist by the Rockefeller Foundation and on July 1, 1987 was elected Director of Agricultural Sciences by the Foundation's Board of Trustees.

Herdt is listed in American Men and Women of Science, was the chairman of IRRI's Long Range Planning Committee from 1981 to 1983 and received the award for the outstanding paper in the American Journal of Agricultural Economics in 1977 (co-authored with Yujiro Hayami). He has co-authored three books and over 60 papers in the field of agricultural development. His most recent book, The Rice Economy of Asia, co-authored with Randolph Barker, is the culmination of their three decades of experience working on that subject. It received the 1986 award for outstanding research communication from the American Agricultural Economics Association.

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WHITHER FARMING SYSTEMS

by

Robert W. Herdt

My topic is "Whither Farming Systems?" Some of my more literate colleagues asked me when they saw this topic whether "whither" was to be spelled with or without an "h," I suppose they were worried about the withering away of farming systems research support. Well, it should be spelled with an "h," at least to begin with.

The word skeptical was used in introducing me, and today my talk is something of a skeptical view. When I was reflecting on why I might have been invited to give this talk, I concluded that perhaps it was because I had never done any research in farming systems and never written a paper on farming systems research or on research from the farming systems perspective. However, I have read a lot of the farming systems literature, and I do have a skeptical view, which I share in this discussion.

The first reason for my skepticism is that I believe that farmers are, as Theodore Schultz said a number of decades ago, "poor but efficient." That is, given what they have, they know how to use it to their own best advantage. So, the women and men who farm using systems are good combiners of information, of resources, of labor and land. If we are going to help improve their living conditions, something has to change to make them efficient. Technology is one of those things that can change. New technology by definition is something that farmers don't know about. Once they know about it, once they've tried it, it is no longer new. One side observation related to this: Those people who want to do research on the "New" Green Revolution varieties are about 25 years too late, because most developing country farmers know about them. They're not new any more, although there may be some still newer ones coming around that are improvements over the first improvements. New institutions, if we can develop and introduce new institutions, may give us opportunity to improve conditions among these poor but efficient farmers. And if policies change, farmers may find themselves in a less than optimal situation; therefore, they may be able to benefit from something that outsiders may have to say.

The second reason I'm skeptical about farming systems research is that I have yet to see results from farming systems research. There have been results in terms of papers, but people don't eat papers, and our business is making people better off, not producing papers. So, how have we made people better off, using farming systems research?

And finally, I would submit that too often farming systems research is professionally and institutionally divisive. In fact, comments to this effect were made in a session of this symposium, not by me.

So, I'm skeptical about a lot of what is done and called farming systems research. I'm not skeptical about its mission or its intention, which I

think, is to generate knowledge to help improve farm-dependent people's welfare by improving their farming systems. I don't know whether everybody would come up with precisely the same definition, but I think that we generally all share this view; that the purpose of farming systems research is to help make people better off, people who are dependent on various kinds of farming systems. I agree with the FSR observation that one of the reasons adoption of some agricultural technology is stymied is that researchers do not adequately put themselves in the farmer's position and adequately understand what is an improvement in his or her farmer system. I would submit that we ought to be looking at four main characteristics of systems. We ought to be looking at the productivity of systems, the profitability of systems, the acceptability of systems and the sustainability of systems. Those are hard things to look at, and because they're hard to look at, farming systems research has evolved the multidisciplinary approach.

In one of these symposium sessions, people asked, "Do we have to have researchers with different disciplines in farming systems research?" We may not have to have one person to cover each of the four criteria, but we need to measure new technology against those criteria. That is, we do have to somehow understand whether, from farmers' points of view, new systems are more productive, are economically enhanced and are acceptable. We also need to consider whether new production systems are sustainable. This is important because in the short run, farmers are not driven by sustainability the way society must be concerned with sustainability over the long run. Faced with the need to examine technology against these four broad criteria, it seems to many of us that the best way is to take a multidisciplinary approach.

The four criteria are difficult to measure, and if farmers are poor but efficient, why don't we simply give them alternatives? Why have farming systems research at all? A very important reasons is to keep us from promoting inappropriate technology with farmers. We need something to warn against pushing inappropriate technologies at farmers through extension, through credit programs, by policies and by various other means. There has been a lot of technology invented that farmers have not adopted for very good reasons. But researchers time after time have bewailed the fact that farmers aren't adopting their technology and have devised programs and policies to push farmers into adopting technologies that for some reason are inappropriate. The farming systems approach has a very useful role in alerting researchers to not fall into that trap. That is not in any way a secondary role; quite the contrary, it is a central role of FSR. If it can be true to that role, FSR has a very important future.

How can FSR ensure that new technology meets the criteria of productivity, profitability, acceptability and sustainability? How to I know, what makes me feel, what makes me believe that farming systems research as presently being carried out is not providing adequate information about those important characteristics of improved farming systems? If there were many new farming systems or modified farming systems being adopted by farmers as a result of FSR, then I would say that farming systems research has had a tremendous impact. And, after my discussion here tonight, you can come and tell me of cases where improved farming systems generated through FSR have made a tremendous impact, If I am overwhelmed with your responses, I'll go away chastened and won't be skeptical any more.

Lacking that, I decided to examine the evidence on FSR. And there is lots of evidence — a whole decade of literature on farming systems research or by people who claim to be doing farming systems research or by people who put farming systems research in their titles. I looked at some of that literature; in fact, I looked at the 158 farming systems research paper abstracts prepared for this symposium. I compliment many of you; some of you I would criticize. You can choose which group you think you fall into when I'm finished.

First let me say that it is evident that the symposium is filled with people who are dedicated to their work and intensely interested in farmers' welfare. I compliment you all on that, and I encourage you all to continue in that. But let me tell you what I found when I examined the 158 abstracts. First, I looked for evidence of multidisciplinary work because my criteria of productivity, profitability, acceptability and sustainability almost require analysis by several disciplines. That is, I think farming systems research by nature has to be multidisciplinary. By my reading, 70% of the papers were reports of single disciplines; of the 70%, they could be roughly equally classed as produced by social scientists, economists and biological scientists. There were only 9% done by what I call physical scientists (agricultural engineers and soil scientists). I was hoping that the ones involving agricultural economists would be multidisciplinary, but they weren't; so we are all guilty.

Another major principle of FSR, and I believe this is valid, is that almost the best way of doing farming systems research is to do it on farmers' fields, not on experiment stations. I looked for evidence of on-farm research, and of the 30% of the reports that were multidisciplinary, 58% involved on-farm trials, and 42% had no on-farm trials. Then I went one step further, which is probably going a little bit beyond what's reasonable: I looked for what I call farmer interaction. If you do an on-farm trial, you almost have to have on-farm interaction. But some people manage to get away from farmer interaction — they do an on-farm trial, and they rent the land from the farmer, but they stay away from interaction with the farmer. What I was looking for was the opposite — trials in which farmers participated, or in which a survey was taken of farmers, or if not a survey, participant observation by an anthropologist was involved. Only about 9% met that final test.

We have another problem, even with good farming systems research, even with multidisciplinary research — on-farm research, good farming systems research, has limitations. It cannot be used to examine or solve all rural-sector problems. There are such things as externalities and market-wide effects. By looking at a farmer's system, by definition one is not looking at the total market. There are policy effects, and a number of the papers moved into those areas while retaining a farming systems title. To me those are beyond farming systems. Good farming systems research can be very productive when it's true to its mission and limitations. Also, farming systems research is problem driven, not paper driven. It can't be motivated by the desire to write a paper. In fact, I think any agricultural research that is motivated by the desire

to write a paper probably is not going to be good in terms of meeting rural people's needs.

I have identified some characteristics of good farming systems research, and I agree that some of it is being done. The question is, why is there not more of it? Why are there so many single-discipline, non-farmer-interaction papers that are not consistent with the precepts of farming systems research? I think there are a number of reasons. Multidisciplinary research is hard to organize, it's messy to conduct, it's hard to report, and journals don't want it. On-farm research is statistically messy; statisticians give people a hard time when they try to do it. It is dirty; you have to go out into the farmers' fields. You have to have transportation, and no experiment station director likes to provide transportation for people to do trials outside the station. And most journals want "rigorous" (disciplinary) papers, so after you go through all this effort, what are you going to do with the results? Well, if you do it, and it's effective, you don't have to do anything more, because it results in a better situation for the people dependent on those farming systems. So why don't people do more good farming systems research? The answer is easy: It's hard to do.

Another thing that is hard is reading 158 abstracts, but my perseverance in reading those 158 abstracts paid off, because I found one that expresses exactly what I've been saying to you and has saved me from writing a conclusion. Let me just read this to you.

> After a decade of fits, starts and occasional successes, farming systems research and extension is losing touch. It is losing touch with farmers, the very people felt by earlier practitioners to be central to the vitality of the farming systems philosophy itself. Academics are elevating the philosophy to the heavy world of models, constructs and software and have distanced themselves from the reality of Third World conditions as perceived through farmers' frames of reference. They are developing their own language alien to farmers; reality is being adapted to software, not the other way around. [This guy's good.] Farming systems research and extension needs to get back to basics. The refreshing experience of spending time on the land with the farmers, jointly puzzling through perceptions, problems and possible solutions will slip away if university faculty don't get their feet back on the ground. The sensitivities and plain hard work prescribed by Norman, Winkleman, Hildebrand and Shaner will be totally replaced by an FSR/E symposium where academics talk about farmers instead of with them. In a sense, the simple-mindedness of the farming systems research and extension concept was its greatest strength. While it is true that this interactive experience must be reported, documented and studied, the study is not the end, the publication is not the end, and the spinoff is not the end. The end is the improvement of life and the productivity of the people on the land.

I thank David Youmans for those eloquent thoughts. The only thing I would add is that if farming systems research and extension do not get back to basics, many will join the cry: Wither, Farming Systems Research!

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Agroforestry Systems

AGROFORESTRY

Agroforestry is a set. of land-use technologies that combines annual and perennial plants, usually food crops and trees. Often fodder for livestock is a critical element of an agroforestry system. Such systems are found throughout the world, but generally they are being discarded as more intensive monoculture systems replace traditional farming, pasture and forest land uses.

Interest in agroforestry has been rekindled for several reasons. Deforestation, soil erosion, water runoff and other symptoms of degradation are alarming throughout the tropics. Agroforestry offers a means to rehabilitate marginal farms and commonlands while producing food, fodder and raw materials needed by resource-poor farm families. Social forestry projects, some focused on private farmlands and some focused on public forests and commonlands, have stimulated foresters to be more interested in agroforestry systems. Agricultural scientists, while primarily still focused on commodity production in monocultures, are increasingly interested in mixed cropping systems and livestock/fodder interactions. Integration of social science into farming systems research of mixed cash/subsistence farm family contexts has reinforced interest in agroforestry.

The papers presented in this section of the farming systems symposium reflect the breadth of interests in agroforestry. Some authors report the empirical results of particular agroforestry systems; some are concerned with traditional conceptual or methodological issues in the context of agroforestry; others are pioneering new forms of integrating disciplinary and professional ideas in the context of agroforestry problems.

The mix of research is a healthy response to the emergence of a new area of inquiry. The clients — resource-poor farm families — will be served by improved knowledge. The applied disciplines that compose the agricultural and forestry sciences will be richer for this new field, and we all will learn a bit more about how to do interdisciplinary research on complex problems.

William R. Bentley, Chair
Bob G. Blackmon, Co-chair

Michael A. Gold

For the past seven years, Dr. Gold's research, teaching and publication efforts have been focused on the role of multipurpose trees (MPTs) in agroforestry systems and the potential of tree improvement programs to improve MPTs. At the present time Dr. Gold is in charge of international programs within the department of forestry. He has been involved in project coordination efforts in an AID/DR Natural Resource Management project in the Dominican Republic, has participated in a Caribbean Basin conference on agroforestry for small farmers in Haiti, and has served as a consultant to the USAID Office of the Science Advisor in Nepal to assist in the development of a fodder tree management research project. He is currently developing a multidisciplinary M.S. degree program focused on social forestry and agroforestry.

UNDERSTANDING INTERDISCIPLINARY RESEARCH AND ITS APPLICATION TO AGROFORESTRY SYSTEMS RESEARCH

Michael A. Gold and Larry W. Tombaugh[1]

INTRODUCTION

Agroforestry, newest of the international development "buzzwords," brings together many disciplines, both applied and basic, biological and social. Because of its interdisciplinary nature and the diversity of rural development activities and environments in which it may be applied, agroforestry research is inherently difficult to formulate, design, conduct and manage.

Fortunately, there is considerable accumulated experience with interdisciplinary research (IDR) developed by the National Science Foundation, A second source of experience with IDR has been accumulated at the International Agricultural Research Centers (IARCs) such as International Potato Center (CIP) in Peru, through farming systems research (FSR) efforts. These experiences have revealed several ingredients for successful interdisciplinary projects having direct applicability to the funding and conduct of agroforestry research.

Key ingredients include 1) a clearly identified problem to which the research is directed that is so compelling that it attracts the interest of the most capable scientists; 2) the availability of a strong, effective leader with proven, respected research skills; 3) attention to group communication throughout the IDR effort; 4) an identified funding source; 5) a supportive and committed administrative structure; and 6) an "exit plan," permitting and encouraging scientists to return to their disciplines at the end of a predetermined period. The applicability of these principles from other areas of science, particularly FSR, to agroforestry systems research is discussed in this paper.

BACKGROUND

This paper turned out differently than originally planned. The original intent was to draw upon the considerable experiences of the National Science Foundation (NSF) and other U.S. science and technology programs and to identify several case studies of IDR activities. Our interest was in examining widely disparate areas — energy systems, aerospace systems and environmental protection -— and to extract general principles that might be useful to those planning or administering agroforestry systems research (AFSR) programs. As will be discussed, AFSR, by definition, necessitates an interdisciplinary approach; we believe that this is the only viable approach for resolving many types of research questions. The shortcoming is usually not in the quality of the science but in the usability of the results. Problems of use seem to increase dramatically as the research is directed at, or includes, a

[1]Department of Forestry, Michigan State University, East Lansing, MI, U.S.A.

social systems component. More importantly, the shortfalls that we have observed appear often to be based on the same causes.

Our literature review did not produce case studies with direct applicability to agroforestry systems but instead yielded several fundamental principles that appear necessary for successful IDR programs. We do not take a case study approach as originally planned. Rather, we first discuss the nature of IDR and then review specific ingredients that seem to be consistently associated with successful projects or programs in order to illustrate the broader application of the fundamental principles of successful research in interdisciplinary agroforestry programs.

We will present a brief overview of FSR from which we believe relevant examples can be extrapolated and then describe the unique attributes of agroforestry research. While the focus is on agroforestry, we believe that the principles presented in this paper are applicable to other types of research that are inherently interdisciplinary.

RATIONALE FOR IDR

Interdisciplinary research is a method of addressing complex issues that transcend disciplinary boundaries (such as acid rain and tropical deforestation). Disciplines taken separately often do not see the "big picture."

Traditional land-grant-university research has its roots in commodity-based research and remains disciplinary and production-oriented. Scientists find themselves ever more specialized, are faced with an almost overwhelming pool of knowledge in which each individual knows less overall and are being confronted with increasingly complex issues. Scientific research has become uncoupled from the everyday needs of farmers and broader long-term concerns of environmental health. Much of the disciplinary knowledge is no longer congruent with society's knowledge and needs (Lacy and Busch, 1982).

The postwar scientific revolution in agriculture introduced a new set of social and biological conditions. As this new production paradigm spread beyond the confines of the industrialized world and was applied under a variety of different conditions, unforeseen social inequities and ecological consequences arose, along with highly recognized gains in food production, e.g., the Green Revolution.

During this decade we have reached production plateaus in many of our major crops. Scientists face a situation in which it is more difficult to identify critical constraints and solve problems that limit greater gains in productivity and efficiency. Indeed, scientists are now concerned about a host of environmental and social issues, along with global overproduction of agricultural commodities.

The complexity inherent in rural development, particularly those efforts associated with small-scale farmers in developing countries, requires a departure from the traditional single-disciplinary or multidisciplinary

approach, FSR is one mechanism now being implemented to develop solutions to these more subtle problems (Wallace and Jones, 1986).

Agroforestry is the term given to sustainable, tree-based, agricultural land-use systems involving intimate and integrated associations of trees, agricultural crops, horticultural crops and animals in a variety of combinations. It depends upon forestry, agronomy, animal husbandry and horticulture for its major inputs, with additional inputs from soil science, microbiology, ecology, plant breeding, chemistry, economics, sociology, anthropology, agricultural engineering and others.

Increased environmental degradation, deforestation and loss of biological diversity have been recognized by international agencies as critical development issues. Removal of trees in developing countries shows no sign of slowing or opportunity for substitution. The critical and fundamental roles that: agroforestry could play in helping maintain the integrity of many different ecosystems and in farming systems has been recognized, but there is much yet to learn. For this reason, interest in agroforestry research and in implementing this research on an interdisciplinary basis is increasing.

THE KEY TO SUCCESSFUL IDR

Before reviewing the key ingredients for successful IDR, and to avoid confusion, a brief definition of terms and discussion of the meaning of "disciplines" follows.

Disciplinary research — research conducted by one or more scientists within a single discipline. Planning, execution and evaluation are all conducted within the confines of a single discipline.

Multidisciplinary research — group research that involves individuals from several disciplines. The research is planned, executed and evaluated by each person separately and interaction is limited. Management is provided by each disciplinary unit.

Interdisciplinary research — group research involving input from several disciplines working as a team with continual intellectual interaction and conceptual synthesis. Group effort is mutually planned, executed and evaluated. Conclusions are drawn and results disseminated through mutual, effort (Bogor and Boyd, 1982; Sauer, 1982).

Disciplines Versus Interdisciplinary Research

Interdisciplinary research is difficult to organize, fund and manage. Disciplinary boundaries often prevent adequate interchange among scientists. By focusing on only those aspects of the world deemed relevant by a particular discipline, scientists ignore problems that lie outside their competence of awareness (Lacy and Busch; 1982),

Disciplines are composed of a narrow set of overlapping specializations, each with conceptual models, assumptions and jargon. Scientists within a single discipline approach the identification of research problems and

their subsequent design and implementation of research in a similar fashion. This is due in part to a combination of training, reward systems and peer interaction.

The majority of agricultural scientists have little exposure to fields not closely allied to their own, leading to incomplete problem identification (Lacy and Busch, 1982). Each discipline tends to see most, if not all, problems as resolvable through the body of knowledge and approach offered by their disciplines. Other solutions are viewed with skepticism or disbelief.

For example, when faced with the problem of low agricultural production, an array of different research recommendations might be proposed; An agricultural engineer would look at drainage and runoff, tillage, planting and harvesting practices to determine how they might be modified; an agronomist would check yield potentials of the cultivars and associated fertilization rates; an economist might explore the availability of markets and credit; a sociologist would look at the role of the farm family as source of labor and at risk behavior. This example illustrates how disciplinary differences can have a major impact on the manner in which problems are chosen and defined. All approaches are relevant as components, but none deals with the system in its entirety (Lacy and Busch, 1982).

Essential Elements

The intensity of interest in interdisciplinary research is based on an underlying belief that scientific and technological problems have become so complex that solutions will require a fusing of disciplinary capabilities. Constraints to complex goals are themselves complex and therefore require integrated research to find solutions. Agroforestry research, like the more well known FSR, requires an interdisciplinary, holistic approach to solving complex land-use issues and human problems.

In our view, successful interdisciplinary research is that which leads to superior processes, products or procedures for solving problems. In relation to agroforestry systems, such research involves development of conceptual frameworks, methodological approaches and analytical tools needed for refinement and advancement of agroforestry as a discipline.

There is nothing intrinsically superior about IDR. It is useful only if it proves to be an effective means of solving problems. This is a critical observation. It is common for research groups to become so enamored of their interdisciplinary activities — with their newly discovered ability to communicate with each other as scientists — that interdisciplinarity becomes not the means to an end but the end in itself. In these situations, the primary beneficiaries are the scientists rather than the larger public. The goal becomes misplaced or lost entirely.

Problem Identification — A Shared Team Process. The first key ingredient of successful IDR is a clearly defined problem that is so compelling that it attracts the very best scientists. Unless a problem is clearly defined it is easy to lose sight of the goal; this difficulty

is compounded as the number of disciplines involved increases. The common tendency is to continually try to redefine the overall goal in terms of questions that can be answered by the disciplines involved rather than to see how far the disciplines can go together in resolving a problem that is defined (outside of science).

Not only should the problem be clearly defined, it should be defined in a way that will excite the imagination of the very best scientists. Since IDR is complex, there are many pitfalls and opportunities for failure along the way; it is important that IDR projects attract the best scientific capability available. Unfortunately, there is an inherent tendency for weaker and(or) less productive scientists to be attracted to IDR because they feel their weaknesses can be masked in the output of the larger group. Measures to deal with this problem include choosing a strong team leader and including mechanisms for judging not only overall group output but also individual outputs as well. It is usually counterproductive to try to mandate interdisciplinary research. Good scientists must be able to clearly see the problem being addressed and to feel it offers sufficient intellectual excitement to warrant their sustained, cooperative efforts.

The use of interdisciplinary teams permits a rapid and objective evaluation of problems and the definition of project foci. This implies a fairly large initial investment in a project, but if properly executed, it reduces costly errors that could result from overly narrow or biased initial evaluations of problems (Jones and Wallace, 1986).

A clear definition of objectives leads to a clear understanding of each individual's role in meeting the objectives, a realistic project time frame and a mechanism to evaluate the results. When lacking this clear definition, IDR teams get lost in other details and deviate from the main objective.

Specific research objectives must be consistent with the objectives of the organization, attainable within the expertise of the team and realistic in the context of other responsibilities of the team. Specific teams are then organized to implement the objectives.

Group "bloodletting" sessions can be used to draft annual team objectives, as veil as disciplinary objectives. Ideally, the entire team is then committed to the objectives (Francis et al., 1982). The main advantage of a cohesive team effort lies in the resultant ability to maintain overall project momentum and focused interest with a higher degree of probability of achieving the defined technological objectives (Rhoades et al., 1986).

FSR projects attempt to prevent disciplines from dividing into self-interested groups by focusing teams on solving farmers' problems and measuring team success through farmer acceptance of new technologies. Individuals from separate disciplines are then able to identify the nature and value of their contribution to the team effort (Meiman, 1982).

Leadership. The second ingredient of successful IDR projects is a strong, effective leader. Lack of effective leadership is probably the single most common cause of failure in IDR efforts. Although leadership styles vary, there are some common threads. The leader should be sincerely interested in the problem being addressed and committed to its solution and should be of sufficient scientific stature to be respected by the members of the team.

The leader should have a sufficiently broad outlook to be able to understand the diversity of research paradigms and appreciate the potential contributions of various disciplines represented in the project. He/she should he intellectually strong enough to be able to encourage the team to keep their collective eyes on the goal and specific problem being addressed. Finally, he/she should have the patience required to deal simultaneously with a diverse array of scientists, the clients of the research and the sometimes changing needs of the funding agency.

Arriving at the proper disciplinary mix is crucial to the success of the team's effort, and this mix may change over time. Once formed, it is not easy to keep the team together. Difficulties often center on the necessary partial loss of individual and disciplinary identity.

When interdisciplinary teams are formed with members from more than one university department or government ministry, the team leader must make certain that individuals are not discriminated against because their department or ministry does not value the IDR effort as highly as do the others.

Communication. A third ingredient is communication. Regular communication of ideas, results and problems is evidence of a functioning team, not a collection of specialists. Without adequate communication, little team spirit develops, and instead of interdisciplinary research, only multidisciplinary research results. Communication also helps to focus disciplinary knowledge on the problem at hand and creates a team capable of developing a socially and politically acceptable biological/technical solution to the defined problem.

Given the significance of having a group of individuals function as a team, it is an understatement to say that the attitudes and interpersonal interactions of the team members are the key to its success. The lack of a generally accepted model to guide interdisciplinary team research leads to conflict over goals, approaches, leadership, resources and methods.

Interdisciplinary teams commonly have communication problems due to semantic difficulties, frequent use of disciplinary jargon and differences in levels of abstraction and quantification (Bogor and Boyd, 1982; Jones and Wallace, 1986). Inevitable interpersonal conflicts often strain personal relations of team members but can also stimulate a great deal of valuable innovation (Rhoades et al., 1986).

One form of communication, constructive conflict, is viewed as an essential, ongoing phase of the IDR process. As a continual component

of problem-solving efforts, constructive conflict develops mutual disciplinary understanding and respect among team members. This involves a joint learning process for all team members in which the potential role of each discipline is understood and accepted and a common level of understanding is developed. Disciplinary jargon is either clarified or removed, and elementary knowledge of basic principles of all disciplines is shared. Further, constructive conflict helps develop mutual respect for the potential contribution of each discipline and its representative (Rhoades et al., 1986).

The principal benefits of constructive conflict are that it serves to enhance interdisciplinary team communication, focuses disciplines and disciplinary knowledge on the problem at hand, and creates a team capable of developing a potentially acceptable biological/technical solution to the defined problem.

As a result of team interaction and constructive conflict, CIP economists use simpler methods, pay closer attention to the relevance of their analyses (rather than its scientific rigor) and consider other professional disciplines as equal partners in the research process (Rhoades et al., 1986).

Funding. A fourth ingredient – an identified, reasonably stable source of project funding – is needed to attract highly qualified personnel. While potential rewards from successful IDR are great, so are potential frustrations. Difficulties are compounded if most of the intellectual energy must continually be devoted to obtaining funds to sustain the effort.

The importance of a stable base of support for agricultural research was recognized 100 years ago with the passage of the Hatch Act. This law provided funds on a formula basis to each of the state agricultural experiment stations to be allocated to the agricultural scientists at the discretion of the experiment station director. Later, the McIntire-Stennis Cooperative Forestry Research Act provided similar base funds for forestry research. It is generally believed that these two programs played a significant role in the development of modern agricultural technology.

A stable source of funding is necessary to avoid the added burden of scrambling for “soft money” on top of inherent difficulties of IDR. Secure funding, tied to a specific project and specific outcome, leaves interdisciplinary researchers free to concentrate on the task at hand.

Administrative Methods of Facilitating IDR. A fifth ingredient is administrative commitment and support. Successful interdisciplinary research requires a pragmatic sensitivity to the need for creative approaches to innovation that complement (not compete with) traditional organizational structures (Bogor and Boyd, 1982). Unless administrative structures are committed to IDR, the effort will never succeed. This requires a dedication to flexibility on the part of the agency facilitating the interdisciplinary thrust.

There must also be a philosophical and budgetary commitment at all levels of a research organization's administration. Interdisciplinary teams are often composed of individuals from more than one organization. Each organization must be equally committed to joint efforts so that team members can fully participate.

An "institute" or "center" is the most prevalent university-based organization for interdisciplinary research and training. These units tend to be organized around activities involving more than one discipline, an arrangement that allows flexibility. Institutes or centers are natural vehicles for assembling staff, attracting additional funds, indicating institutional commitment and determining responsibility and accountability. They are, therefore, likely mechanisms for IDR and are capable of bringing the university more in touch with the contemporary needs of society (Bogor and Boyd, 1982).

Exit Plan. The final ingredient of success is an exit plan. There are three important reasons for building an exit plan into an IDR activity. The primary reason is to prevent indefinite perpetuation of a research activity beyond its specific purpose. This avoids the common pitfall of having a project gradually increase its number of participating scientists. At NSF, a successful method has been to keep tight control over IDR activities, providing a mechanism to rid IDR projects of weak and(or) less productive scientists.

The second reason for the exit plan is to prevent the research from continuing for the sake of interdisciplinarity, losing sight of its specific goal.

Third, it is important to design IDR efforts to enable scientists to be permitted, even encouraged, to return to their disciplinary activities. Such planning will help attract the most capable scientists and encourage problem resolution.

ADVANTAGES AND DISADVANTAGES ASSOCIATED WITH IDR EFFORTS

Advantages

Enhanced creativity and synergism come about through interactions with those outside one's own discipline. Interdisciplinary research teams have the potential to develop a systems approach by drawing on a wider range of perspectives to address a problem. IDR teams can broaden the scope of problem identification and application of new information.

Experience gained through interdisciplinary research at CIP has led FSR teams to move away from complex experimental designs for on-farm trials toward simple designs that can be readily understood by farmers. Similarly, increasing emphasis has been placed on informal survey methods that get the principal investigators into the field (Rhoades et al., 1986).

Disadvantages

Insularity among agricultural sciences has serious scientific and social implications. It suggests that disciplinary problems are likely to receive more support than those that cut across disciplinary lines. Since disciplinary problems are more easily defined, easier to assess in terms of disciplinary significance and more likely to contribute to the main body of disciplinary knowledge (Lacy and Busch, 1982), it is easy for disciplines to become isolated from one another.

Consequently, there are many disincentives to participating in interdisciplinary teams. These include a lack of rewards, incentives and promotion potential; a lack of trust of other disciplines; common feelings of inferiority or superiority among disciplines and individuals; and unequal commitments at the level of cooperating institutions, departments or individuals (Meiman, 1982).

At CIP, the structure of rewards and pressures for quick results creates strong tensions within and among teams, destabilizes them and biases the research to the short-term payoff (Rhoades et al., 1986).

APPLICATION OF IDR TO AGROFORESTRY SYSTEMS RESEARCH

Since the Green Revolution of the 1960s, no revolutionary new techniques have gained wide acceptance. New adaptations of existing technologies, in both industrial and developing economies, are confronted with a multitude of constraints. These constraints result from formerly unrecognised (or glossed over) biological factors or interactions that arise between system components and from an increased sensitivity to the social characteristics of the target group of intended beneficiaries -- small-scale farmers -- toward which technologies are directed.

Over the past decade, the planning of agricultural research at the IARCs and other international and national research centers has been undergoing a. revolutionary overhaul made possible by the development of FSR methodologies (Shaner et al., 1982). By deriving research priorities from a diagnosis of problems and potentials in existing farming systems and by using on-farm research methods to assist in the development of optimum technologies, FSR has done much to augment the effectiveness of traditional component-oriented commodity-research-and-development programs (Wallace and Jones, 1986).

Although firmly grounded in a search for a more holistic approach to rural development, both agroforestry and farming systems research suffer from a tendency towards a certain narrowness of conception that betrays their origin. Farming systems research is something that agricultural researchers talk about. Initial work on farming systems focused almost exclusively on crops and has now been expanded to include livestock; however, it rarely gives trees and tree crops more than cursory attention. Agroforestry is something that foresters talk about, focusing for the most part on the tree components of rural production systems (Taylor and Soumare, 1984).

Agroforestry is the most recent “buzzword” to catch fire and spread throughout the globe, as “Green Revolution” and “farming systems” did in the 1960s and the 1970s, respectively. Although the term became widely known, it is frequently misunderstood and implies different things to people from different parts of the world, to people with different training and to people in different hierarchical levels of the “development” bureaucracy.

Typical of a new buzzword, agroforestry has excited the imagination of donors, politicians, planners, scientists and nongovernmental organizations. Donor research dollars and international, regional, national and local political support are available for agroforestry projects. The International Council for Research on Agroforestry (ICRAF) recently celebrated its tenth anniversary.

Many of the IARCs have incorporated an agroforestry component into their overall research thrusts. For example, the International Institute of Tropical Agriculture (IITA) has been a leader in the development of the “alley cropping” concept as a tool in FSR. The International Livestock Center for Africa (ILCA) has an active research program in the use of trees as a source of animal fodder.

If this tremendous groundswell of interest and support is to be sustained in the long term, as it must be if agroforestry systems are to have a major impact, then well-meaning, yet ill-conceived, uncoordinated, parochial, piecemeal research projects with no solid intellectual grounding must be avoided. We must develop a reliable method of identifying agroforestry research priorities and subsequent IDR methodologies (Raintree, 1984).

In response to the complex problems associated with agroforestry, an interdisciplinary approach is being taken to research on these systems, such as was done for farming systems. Research on agroforestry systems requires new combinations of methodologies and strategies. This approach must avoid the disciplinary bias that can cause an investigation to overlook factors of importance that either overlap disciplinary boundaries or that are not directly concerned with biology. The composition of the research team cannot be fixed but will include both biological and social scientists.

Agroforestry is fortunate to be able to directly incorporate much of the FSR approach and build it into the foundations of its own newly emerging research tradition. There are, however, important differences in the nature of these two overlapping but distinct types of research. Therefore, agroforestry must develop its own research methodology (Raintree, 1984).

In contrast to FSR, technologies enabling the promise of agroforestry to be fulfilled are still in the developmental stage. As is now well known, agroforestry is an ancient system of land management but very new as a "scientific" discipline. It has developed to fill the now-painfully-obvious disciplinary void between and. agriculture and forestry. It has potential to play a valuable and, in certain instances, vital role in both fragile ecosystems and. highly productive

systems wherever human pressure on resources creates a need for an efficient, diversified and sustainable land-use system (Raintree, 1984). If this potential is to be realized, a great deal of scientific research is necessary -- the time it takes to achieve major breakthroughs will be measured in decades, not in years.

Agroforestry production systems bring unique problems for agricultural development. A specially adapted, broader approach to the diagnosis of relevant problems is required due to the variety and complexity of potential agroforestry systems; the long production cycles; the myriad combinations of crops, animals and trees; the need to carefully consider long-range land tenure implications; and the value placed on conservation in land-use interventions. Of even greater importance is a pressing need for a more systematic, detailed and open-ended technology design to follow problem diagnosis (Raintree, 1984).

In FSR, the purpose of the diagnosis is frequently used to identify relevant applications for proper selection from an "existing inventory" of well or partially developed technologies (i.e., postharvest storage problems or further variety selection). In contrast, the inventory of available solutions and scientifically understood and validated technology packages developed through AFSR has yet to be developed (Raintree, 1984).

In a typical FSR project, the addition, modification or refinement of a technology permits easy visualization of proposed modifications to the current land-use system. Contrast this with AFSR, where the newness of the science and technology and complexity of possible agroforestry interventions make it imperative to first conceptualize the nature of the improved system.

After conceptualization, it is necessary to develop functional design concepts for system-improving interventions, work out specifics of relevant agroforestry technologies and assess whether or not these suggested technologies exist or, more likely, are still in need of development and refinement. One can then consider what research is needed to develop or adapt the identified technologies and finally come to the question of experimental design (Raintree, 1984).

ICRAF has developed a diagnostic and design methodology to accomplish the above in the African context (Raintree, 1984). Diagnosis and design comprise a complex process that is not yet widely known or used and is undergoing modifications to account for regional differences in agroforestry systems around the globe.

CONCLUSION

Experience gained from FSR projects indicates that two major challenges face interdisciplinary team researchers: 1) getting social scientists (commonly anthropologists and economists) to participate in all phases of technology generation and transfer within agricultural research and development projects and 2) getting biological scientists to accept the

reality that improving farmer practices requires more than technical solutions (Rhoades et al., 1986).

Integration of disciplines will be required to foster more effective research and extension programs. While maintaining disciplinary integrity, the result of an IDR team project is a generally broadened understanding of the subject area (agroforestry) and concurrent development of a more holistic outlook. This interdisciplinarity will help in the development of alternatives (including agroforestry) for the future (Rhoades et al., 1986).

There are many unique opportunities for interdisciplinary research in agroforestry systems. These include working to solve real problems and not to simply address isolated pieces of problems, thus providing a scientific arena in which conceptual frameworks, methodological approaches and analytical tools of any given discipline are challenged. This challenge allows for clarification of the scope of a discipline's approach. Within this confrontation is potential for refinement and advancement of agroforestry as a discipline.

Interdisciplinary research challenges a scientist to defend and expand his/her repertoire of methodological approaches and analytical tools (Russell and Sauer, 1982). This is critical to AFSR because it is a new field of endeavor. Finally, IDR offers opportunities for professsional development. It also provides opportunities for graduate students working with scientists involved in IDR to learn various scientific approaches, analysis of complexity and integration of multiple criteria.

Agroforestry and agroforestry research are seen in the United States as being closely linked with development assistance efforts. Development assistance agencies, then, have a particular responsibility to further this important research area. Serious attention needs to be given by policy-makers in the U.S. Agency for International Development and similar agencies to developing mechanisms for providing a reasonably stable source of support for research areas such as farming systems and agroforestry systems.

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USE OF ETHNOECOLOGY IN AGROFORESTRY SYSTEMS RESEARCH: AN EXAMPLE OF AGROFORESTRY TECHNOLOGY AND PEST-MANAGEMENT RESEARCH IN KENYA

Dianne Rocheleau and Luis Malaret[1]

INTRODUCTION

The methods for agroforestry research in general, and community-based agroforestry research in particular, must constitute a radical departure from traditional agronomy research and even from many of the farming systems research (FSR) methods now accepted in formal scientific circles. In formal or informal research programs, the approach should often be more ecological than agronomic, as befits the focus on the place of trees, woodlands and savannas in the habitat of farmers and herders. Both qualitative and quantitative sampling and monitoring techniques have been developed to study whole systems and the complex relationships between organisms and their environments (Odum, 1983; Conway, 1985). Moreover, the theory and the methodology are well suited to a sliding scale of analysis from tree-soil interactions to regional land-use systems (Odum, 1983; Hart, 1986; Conway, 1985) whereas agronomy is firmly rooted in the plot.

The development of agroforestry and woodland-management systems for rural landscapes can benefit particularly from the convergence of methods in two subfields of ecology: ethnobotany and agroecology. While ethnobotany draws its methods from human ecology and ethnographic traditions in anthropology (Fleuret, 1979; Richards, 1985) and naturalist traditions in plant and animal ecology (Okafor, 1981), agroecology derives its research methods more from environmental management and systems ecology (Hart, 1980; Altieri, 1983; Conway, 1986). The careful combination of methodologies from these sources provides researchers with a rich selection of tools for studying existing "natural" ecosystems, traditional agroforestry and woodland-management systems and recent innovations by rural people. Methods from both approaches present ample scope for incorporating indigenous technical knowledge, indigenous capacity for innovation and indigenous capacity for formal experimentation into identifying species for domestication and designing and testing new agroforestry and woodland-management systems.

For example; researchers can nest ethnobotanical and ethnozoological data and sample collection methods within a series of informal interviews with rural community groups of 15 to 30 people. These interviews can then be followed by systematic, "chains" of household-level and individual interviews, mapping of farms and collection areas and participation in gathering trips, processing and other activities. The same kinds of activities can be used to monitor and evaluate experiments, whether formal or "informal." The experiments can be on station, on farm or in the forest, over a wide range of "user" and

[1]Formerly ICRAF, currently Ford Foundation, Box 41081, Nairobi. Kenya; University of Nairobi, Dept. of Zoology, P.O. Box 30197, Nairobi, Kenya.

“researcher” partnerships with respect to environmental design and management. The possibilities range from researcher-designed experiments on station to rural people’s own experiments that are simply “discovered” and documented by research institutions.

Most community-based research on landscape and plant domestication will focus on ecological adaptations of FSR in situations where the user is also a researcher. However, the exact choice of methods and how to combine and apply them is still largely a matter of taste, style, bravado and available resources. For most researchers, first attempts with such an approach will constitute a personal experiment. The challenge is to derive a coherent methodology from an eclectic collection of methods and to answer research questions framed in response to distinct local circumstances.

AN EXAMPLE FROM KENYA: TRIALS, ERRORS AND HINDSIGHT

The example that follows does not constitute a model; to the contrary, it presents a report of an experiment. The emphasis is on lessons learned and implications for follow-up in site-specific, methodological and topical terms. An exploratory, on-farm, agroforestry research effort conducted by the International Council for Research in Agroforestry (ICRAF) in Mbiuni Location, Machakos District, Kenya, provided a convenient context for testing a combination of farming systems research and extension (FSRE), indigenous technical knowledge and ethnographic and ecological research methods for domesticating indigenous plants in agroforestry systems and designing pest-management technologies.

The Original FSRE Project

The original project was a test of the diagnosis and design (D&D) method (ICRAF’s adaptation of iterative rapid rural appraisal: ICRAF, 1983a and 1983b; Raintree, 1983; Vonk, 1983). The D&D survey focused on the farm level. Farmers identified priority problems for agroforestry research to address: poor soil fertility, inadequate soil moisture and dry-season fodder shortages, as well as shortages of building material and fuelwood. The proposed responses included alley cropping with *Leucaena leucocephala* for mulch and fuelwood and rehabilitating grazing lands by planting scattered multipurpose trees in microcatchments. Ten farmers each tried one of these options in informal trials (on-farm, researcher-designed, farmer-managed) (Vonk, 1983; Raintree, 1983); Rocheleau, 1985).

Later work at the community level and follow-up of the original 10 farm trials provided a wealth of information and innovations, based upon 1) involvement of self-help groups in tree propagation and planting, 2) participating farmers’ reactions and proposed alternatives to the original technology trials and 3) reactions of the group members to their own tree-planting efforts on farm and to the original 10 trials (Rocheleau, 1985). The researchers joined self-help groups as participant observers in weekly soil-conservation sessions and proposed agroforestry practices to supplement structures at gully and grazing

land rehabilitation sites (Hoek, 1983; Rocheleau and Hoek, 1984). Participating farmers requested that seedlings be distributed for on-farm planting rather than “wasted” on the conservation sites. At planting time project staff distributed “sampler packages” of 13 exotic tree species to active participating members (120) of five collaborating self-help programs. Species distributed were Citrus spp., Anacardium occidentalis, Psidium guayava, Cassia siamea, Carica papaya, Leucaena leucocephala, Acacia holosericae, Acacia albida, Azadirachta indica and Melia azidirach, along with a limited quantity of Sesbania sesban, Gliricidia sepium and Albizia amara, all from government-energy-project nurseries. Each participant had agreed to allow follow-up surveys and to observe and report on the performance of the trees. Other members of the community expressed interest in securing seedlings for the next planting season; within a few months, six groups requested assistance to develop small nurseries and to grow their own seedlings (Rocheleau, 1985).

While the original on-farm trials were researcher designed and farmer managed, the group activities led to small informal trials by individual members, as well as to the “discovery” of previous efforts by a few local tree specialists. The new trials were informal and exploratory and often incorporated either the function or the form of the alley cropping and grazing-rehabilitation technologies, but rarely both. When group members were invited to visit and discuss some of the original on-farm trials as a group, they not only shared their very critical opinions about the “package” in question, they also “adopted” the process of agroforestry development as a community enterprise.

By presenting farmers with the intentions of the trial and the reasons for particular design features, researchers gave the participants a basis for critiquing it constructively rather than simply accepting or rejecting it. During the course of the discussion, participants raised several critical points about the trial technologies, which led others to pose alternative designs. For example, one woman suggested applying large amounts of bulky plant biomass trimmed from living fences of Euphorbia terucalli to bomas (cattle pens), to be soaked with urine, trampled and baked into the underlying manure and soil -- instant compost! As this practice was discussed in group meetings, many people indicated experience with the technique or showed an interest in trying it. Others reported having used Terminalia brownii and Combretum spp. leaves from large, dispersed trees. Within the year most farmers in the vicinity had tried this at least once after trimming their Euphorbia hedges. The next logical step seemed to be refinement of the technique or a progression into composting nearby in order to increase the nutrient content and to increase bulk without fouling bomas.

Another member, who visited and discussed trials on the same farm, planted a wood and timber lot on degraded cropland, as well as living fences and timber on her property boundaries, and a mix of fodder and timber trees in a small pasture near her home. Yet another of the women who visited the trials went on to plant three species of fruit trees in lines at 4-m intervals on her cropland and a checkerboard pattern of Leucaena in her vegetable garden for wood and mulch. Three others present at the same group discussion followed up by planting trees for

fodder or for small poles on cropland with one of the same species and the same spacing as the alley cropping trial. These farmers were not adopting a proven package but saw themselves as choosing, mixing and matching from a selection of possible practices with some demonstrated feasibility.

Group participants began to request seeds and seedlings of particular species or to specify desired characteristics of introduced species and practices. As farmers tended their newly planted trees, they also got a keen sense of the vulnerability of some exotic species to drought, browsing, trampling and termites, which fueled an interest in indigenous trees. This coincided with the perception of researchers, who could find no reason to give preference to exotics except for reportedly lower growth rates of indigenous trees (based more on supposition than fact) and a research tradition based on the introduction of “high performance” species from “somewhere else.”

As more indigenous species became available in group nurseries and from other nurseries collaborating with the project, some farmers requested large numbers of Acacia tortilis and Acacia polyacantha for woodlots while others wanted only exotic fruit trees. As the seedling distribution proceeded, researchers observed farmers bartering their trees with neighbors - three fodder trees for a fruit tree, or several indigenous Acacia spp. for an exotic timber tree. This trading activity, as well as the subsequent disposition of the seedlings, provided researchers with information about who wanted what kind of trees, for what purpose, and where they were willing to put them.

Out of all the initiatives taken and new questions posed during the course of these community activities, several potential research directions emerged, among them:

1. Composting based on tree biomass.
2. Mulching based leaf production from dispersed trees or blocks of trees outside the cropland.
3. Screening of indigenous trees for agroforestry systems in croplands and in-between spaces.
4. Propagation methods of popular indigenous species.
5. Screening of drought- and termite-resistant Eucalyptus (timber) species from the dry lands of Australia.
6. Crop combinations and spacing for small home gardens.
7. Pest control for agroforestry practices.
8. Management and rehabilitation of grazing and woodland-collection areas by and for gatherers.

The group-level activities also resulted in a transfer of tree-propagation-and-planting technology from the hands of a few skilled and relatively well-off men to most farmers in the community, the majority being women. As in similar cases elsewhere (Sumberg and Okali, 1987), involvement in these activities changed the species, spaces and processes that shaped the research agenda.

These research priorities reflect some of the principles of alley cropping selected for development in very different contexts. Farmers

clearly took an interest in 1) the use of plant biomass for soil fertility (point 1 from list); 2) the use of leaf mulch, but from dispersed trees or trees outside cropland (point 2); and 3) multistory systems for intensive land use (points 6 and 8). They also adopted the process of agroforestry development and domestication of trees (points 3 and 4), incorporated particular species from the trials (points 5 and 6) and sought solutions to problems from their own tree-planting experience (points 5 and 7). This is distinctly different from the classical sequence of 1) species selection and genetic improvement of plant material; 2) development of prototype technology; 3) adaptation of prototype to specific sites; and 4) widespread extension of a fixed package. By contrast, this experience would argue for introduction of many species and a few sample technologies with the emphasis on 1) principles and 2) demonstration of some promising components.

Spin-off Ethnoecology Projects

Two spin-off projects addressed the issues of women's use of off-farm lands and gathered plants, the interest in domesticating indigenous plants and the identification of termite- and drought-resistant species (whether local or exotic). The first, an ICRAF training-and-action research project, sought to address the use and management of off-farm lands and resources and to develop alternatives that would serve those women most dependent on products gathered off farm. The first round of activities focused on the identification of those species and spaces most important to gatherers and on their interest in devising sustainable woodland-management systems or in domesticating favored wild species into agroforestry systems on farmers and homesteads. A second, independent research project set out to explore the role of termites as a factor in species selection and design of agroforestry practices, to study the ecology of the species present and to determine the potential for termite control, including agroforestry technologies to resist or repel termites.

Summary of the common approach used. In keeping with the eclectic, exploratory approach of the original project, several methods were used to describe the role of indigenous plants and termite species in local land-use systems, document local knowledge and practice, identify recent innovations in plant management and termite control and develop priority topics and appropriate formats for trials with and by farmers. Both efforts employed informal surveys of groups, households and individuals to document local knowledge of the flora and fauna among both the community at large and acknowledged local experts (Pope, 1986; Rocheleau, 1985; Malaret & Ngoru, 1986).

Interviews and discussions with groups built on prior contacts from the original farm trials and the subsequent group activities in soil conservation, tree planting and tree propagation. Household interviews and lengthy discussions with specialists followed from the group meetings where the purpose of the research and the range of topics had already been introduced and specialists had been identified. These encounters, in turn, often led to participant observation on gathering trips, termite digs or visits to sites of tree planting, termite control or domestication of wild food and medicinal plants (Rocheleau,)

1985; Malaret and Ngoru, 1986). Specialists often set additional appointments for long discussions and gathering trips to distant collecting areas or special off-farm gardens (Wanjohi, 1987; Wachira, 1987). Researchers also conducted opportunistic interviews and engaged in participant observation when they happened upon people digging out or otherwise treating termite mounds, herding animals or gathering food, medicine or fuelwood.

The indigenous plants study: methods and results. The group discussions on gathering indigenous plants normally lasted from 45 minutes to 1 1/2 hours, with 1 to 30 people present. The early group interviews were characterized by listing of plants gathered and places used for particular products, with some group members noting the points and others raising their hands to indicate whether they used the same plant or place. Later, the group discussions dealt more with reasons for practices and preferences, problems with gathered plants and source areas and ideas for improving the situation. Eventually the group meetings tackled decisions about which plants to domesticate, where and in what combinations. Interviews often ended with questions or decisions for participants to consider, followed by one or two repeat interviews. The technique was suggested by the groups themselves and the farmer-research-extensionist, in order to give people time to think and to confer with family and friends (J. Kyengo, personal communication; Vonk, 1986).

The household and individual interviews lasted from 1 hour to all day, depending on the disposition of the person involved and the availability of researchers to accompany them on gathering trips. The household and individual interviews also varied in format, with both formal and informal approaches used at various times. One informal but in-depth survey about specific plants and environments based the sample on a chain of informants from “average” to expert (Rocheleau, 1985). A more formal survey of 63 households (5% sample of population) asked specific questions about the environment, terms of collection and processing and use of wild plants, as well as species preference and decisions about domestication (if, how and where) (Mutiso, 1987; Wanjohi, 1987; Munyao, 1987; Wachira, 1986; Rocheleau, 1985). The formal survey took three times as long and reproduced the same results as the group interviews and “chain” of individuals, with less detail and coherence of context. The residence of the outside researchers (part time) and farmer-researchers (full time) in the area also provided ample opportunities for farmer-initiated interviews and information exchanges.

During group, household and individual interviews, as well as on gathering trips, the field researchers collected samples of all plants named except for a small number not in season or not readily identifiable at the time (Rocheleau, 1985). In some cases, researchers accompanied specialists to distant collection areas, if the plant samples were not available on or near participants’ farms or homesteads (Wachira, 1987; Munyao, 1987; Wanjohi, 1987). The plants were identified at the University of Nairobi Herbarium and the information compiled for use by ICRAF and for reference by the local community (Raintree et al., 1987).

The surveys of women's use of off-farm lands and gathered plants yielded a list of 65 indigenous species used for food an 99 used for medicinal purposes, among them woody species, wild leafy vegetables and wild roots (Rocheleau, 1985). Most of the woody species were also major sources of wood or fodder, uses that received more attention in previous surveys of the farming system. In the formal survey 90% of the 5% sample group reported using gathered leafy vegetables to some extent, 10% said they used wild greens year-round, and 70% reported that they or their children ate wild fruits daily (or whenever available). Most of the respondents also used herbal remedies.

In many cases people noted that wild plants played a particularly critical role at some times of the years. Some of the wild greens, such as Commelina Africana (Kikowe), were especially important for late planters (i.e., poor people who "borrow" or rent oxen) because these greens filled the gap between the onset of the rains and the first harvest of cowpea leaves from the cropland. Likewise, some vegetables (Solanum nigrum and Amaranthus spp.) and fruits were especially important during the dry season: over 25 species of fruits were used by the sample group during that time (Wanjohi, 1987; Mutiso, 1987; Wachira, 1987). Of all the species listed, farmers identified four species of leafy vegetables, nine fruit-bearing species and seven medicinal plants as good candidates for domestication on farm (Table 1). The criteria cited for choice of species also helped to define appropriate planting niches and plant combinations.

Most women surveyed were interested in alternatives to gathering woodland and fallow products in shrinking, degraded and sometimes distant collection areas. They were receptive to the domestication of indigenous trees (including wild fruits) and wild leafy vegetables in gardens, small tree plots near the home and in in-between spaces such as boundaries, gullies and along drainage and soil-conservation structures (Rocheleau, 1985). The groups and individuals surveyed were also overwhelmingly pessimistic about woodland management, except for those who actually owned sizable chunks of land with bush and woodland vegetation (Wanjohi, 1987; Wachira, 1987).

Throughout this cycle of surveys and plant collection, the tree planting extension continued, with substantial informal feedback to the research effort from participant observation in group work sessions. Moreover, the surveys sparked new interests, which in turn fed back into extension and informal trials. Several female farmers who had participated in group and individual interviews requested assistance with the design and establishment of small home gardens for plant domestication. They also requested help in procuring seed, cuttings and "wildlings" of indigenous trees, vegetables and vines, as well as exotics such as South and Central American Amaranthus spp. Although field workers had not planned to initiate such trials until later, they complied with the requests. Each of the farmers decided where to place the garden and cleared, tilled and fenced the plots prior to planting time. Researchers collected seed and "wildlings," provided them to participants and helped to propagate and(or) plant them (Wanjohl, 1987; Wachira, 1987).

Most of the gardens were roughly 9 m^2 to 15 m^2, situated near the home and fenced with thorny Acacia branches and other dead wood or living fences. In every case soil fertility was a major concern in site selection. The factors that influenced selection of indigenous wild species for the gardens included abundance, ease of access and palatability (for both fruits and vegetables). Also important as selection criteria for vegetables were preparation requirements. The indigenous vegetables most commonly planted were Solanum nigrum, Cucumis dipsaceus and Amaranthus spp. (exotic and indigenous), while Ximenia caffra, Thespesia danis and Carissa edulis were the wild fruits most often chosen. Wildlings and seeds for some of the increasingly scarce, favored fruit species, such as Sclerocarya birrea, could not be found.

Some participating farmers asked if they “might please include some exotic fruits and vegetables as well” (Wanjohi, 1987). This was in fact expected by the field researchers, much to the delight of the farmers. It suggests that people don’t really feel free about experimenting until they have independent access to seed or cuttings and can propagate plants themselves.

Of the seven garden trials established during this season, five “succeeded.” Success, as defined by the farmers, mean that gardens produced enough green vegetables for home consumption or at least enough to reduce the need for gathered or purchased greens, or that gardens produced vegetables that were more palatable and easier to prepare than the usual mix of gathered greens. Fruit trees were considered to be a tentative success if they established well without serious damage by pests, diseases or drought. Another measure of success was the degree of interest expressed by self-help groups and individual farmers (again, almost exclusively women) in these gardens. As in other cases, they expressed their interest in terms of the principles and the components involved: development of vegetable gardens in homesteads and group sites, homestead fruit trees, mixed tree nurseries and vegetable gardens at group and homestead sites and multistory home gardens.

Those whose gardens failed, as well as the “successful” gardeners, cited the same problems (though different in degree): browsing by livestock, insect pests and drought. This mirrored many of the same problems experienced in earlier alley cropping and grazing-land trials. However, given the size and the location of gardens, farmers found these problems much easier to address. Home gardens also present a much lower risk environment for experiments and allow farmers to observe the entire system close at hand. Yet, even in this limited space, farmers must deal with a whole constellation of related innovations that are necessary to support the introduction of new plants, multistory spatial arrangements and other new management practices. These innovations include control of animal movements and(or) effective fencing, pest control, water harvesting, intensive soil management (composting, deep tillage) and research and training in seed selection and plant-propagation and plant-management techniques. Eventually several principles and components from these garden “trials” will likely find their way onto cropland, grazing land and in-between spaces in the larger landscape.

The termite study: methods and results. Group interviews with three self-help groups followed a format similar to that of the indigenous plant survey. The first meetings were attended by the entire group, predominantly women with a few senior men. The discussions lasted from 45 minutes to 1 hour and focused on a listing and description of termite species and habitats, type and degree of damage and resistant plants.

The farmer-translators, with the local community, then selected 30 farmers considered to be knowledgeable about termites. Their participation consisted of two to four interviews, progressing from general discussions to repeat visits to verify termite identification and information on crop damage and in some cases to map termite mounds and land use on individual farms. During the initial interview, farmers provided information on Kikamba names and description (e.g., morphology, habits, color) of termites known to farmers, soil/land-use preferences of termites in the area, cultivated and wild plants attacked by termites, stage and condition when attacked, resistant and repellant plants (dead or alive) and control practices and their effect on termites. Whenever possible, termites and plants described by interviewees were collected on the spot and later identified by genus (termites) or species (plants).

Farmers identified six “classes” of termites based on descriptive and functional characteristics, including size and color of worker caste, time of activity, structure of covered surface runways and (for mound builders) shape and structure of the mound. The farmer’s classification scheme showed a high degree of internal consistency as well as close correspondence to six termite genera (Table 2).

Farmers identified humus, wild grass, 5 annual crops and 25 perennial plants that were attacked by termites (Table 3). This provides one basis for screening plants for agroforestry systems. For example, Terminalia brownii is widely reputed to produce termite-resistant timber. Yet farmers reported heavy attacks on wild seedlings and attribute regeneration to the large number of seedlings present. While natural stands can sustain heavy losses, this would be disastrous for programs based on expensive nursery seedlings. Farmers also reported a positive effect on the natural reproduction of Terminalia brownii. They noted that termite attack on the winged fruit hastened seed germination. This report warrants further discussion and verification during the coming year.

Of the five major annual crops, only sorghum and cowpeas appeared to be attacked by less than five termite genera. Sorghum was attacked by only one genus and was in fact the traditional staple crop before the introduction of maize and other annual crops. Several farmers noted that maize was attacked sequentially by different termites, some of which were distinguished by the part of the plant attacked:
1a) Odontotermes, attacks roots; 1b) Microcerotermes, attacks roots; 2) Macrotermes, attacks base of plant; 3) Allodontotermes, attacks maize after it has fallen on the ground.

Aside from identification of resistant and vulnerable plants, these data provide an estimate of the breadth of the food niche of each termite

genus. Macrotermes and Odontotermes have the greatest food-niche breadth, followed by Microcerotermes and Allodontotermes and then by Cubitermes and Pseudocanthotermes. Knowing the range of plants attacked and those plants most often attacked would allow termite genera to be ranked according to threat posed to farmers. It would also allow the elimination from agroforestry trials of plants that are susceptible to attack by a locally abundant type or by several termite genera. The most resistant plants could, of course, be favored.

All farmers interviewed stated that termites attacked healthy plants as well as unhealthy, dead or dying plants. This is counter to the conventional view among foresters that termites do not attack healthy plants except in cases where dead tissue (e.g., bark) is fed upon. The answer to this controversy is of vital importance if farmers are going to maintain tree nurseries and seedlings in areas where termites are widespread.

Farmers listed 36 species of perennial plants resistant to termite attack. Those listed most often are Gnidia latifolia (24 farmers), Zathoxylum chalybeum (15) and Musa spp. (12). Based solely on the quantitative results of the survey, these three species would have been considered the most promising candidates for agroforestry trials of termite-repellant species. However, more credence was given to the longer lists of resistant trees provided by farmers known to have long experience in horticulture, tree planting and management of indigenous trees. Farmers attributed resistance to both chemical and physical properties of the trees, such as presence of latex or hardness of the wood.

Previous studies have shown that the number of species present and the abundance of each are greatly affected by soil type and land use (Wood, 1975; Wood and Johnson, 1978). To examine this relationship at the study site, researchers have mapped termite mounds according to land use and soil type (thus far on four farms in each of the four soil types in Kathama). Combined with the farmers' data, these maps can provide information about soil and land-use preferences of the mound-building termites that farmers have identified as major pests. The effect of land use and soil type on the diversity and density of termite genera would have serious implications for the design of agroforestry systems. Placement (on soil and land-use type), spatial arrangement (clustered or scattered) and tree species would all be influenced by, and would in turn influence, the distribution of termites and their impact on other associated crops.

Farmer reports and the observed distribution of Macrotermes and Odontotermes mounds indicated that termites are more common on red and sandy soils and less common on black common soils (Vertisols). Odontotermes seemed far more restricted in its soil preference than did Macrotermes. Farmers also stated that more termites were found on the croplands and grazing lands than were found on the home compound or in the bush. Field observations placed the greatest number of mounds on cropland, followed by grazing land, home compounds and bush. Odontotermes mounds were more restricted to cropland than were Macrotermes mounds.

Control methods mentioned by the farmers included direct destruction of the queen or the nest, the use of barriers, changing a component of the land-use system and changing the land-use system (Table 4). There was little agreement among farmers with regard to the impact of the several land-use and crop-management changes. Six farmers did note that the construction of terraces appeared to concentrate the mounds on the terraces and reduce the number of termites in the surrounding area.

To pursue further research on the relationship of land use to termite abundance and activity, more precise information would be required on the chronological order of changes in cropping, land use and control practices. This would allow for a better interpretation of the present distribution of the termites. Farmers' knowledge of the interactions among termite species (e.g., competition, mutualism) and among termites, other pests and their natural enemies (predators, parasites could also lead to the discovery of biological control agents (e.g., ants, birds, plants). More detailed information on climatic effects (in particular the seasonal and year-to-year variation in rainfall) on the foraging and reproductive activities of termites might help to explain the intensity, frequency and fluctuation of termite damage. This, in turn, could influence the timing of tree planting and termite-control activities.

Preliminary Indications from the Two Studies

Several indications for the continuing research and extension efforts at Kathama emerged from the termite and indigenous-plant surveys, the garden trials and ongoing agroforestry extension activities:

- The scope for community-level planning of land use and resource management has been substantially reduced by prior land adjudication (1972) in Kathama. However, the experience of this community underlines the need for agroforesters and local residents to deal with these issues in other areas before many agroforestry and woodland-management design possibilities are preempted by simplistic patterns of land allocation in complex landscapes.

- The interest in domesticating indigenous wild plants (trees, shrubs and herbaceous plants) is substantial in warrants a vigorous research-and-extension program to follow up on those species identified for domestication or for protection and management in place. This would include the selection of germplasm and techniques of propagation, as well as the placement and management of the plants in cropland, grazing land and other niches in this increasingly agricultural landscape. The continuing introduction and testing of exotic plants would proceed according to the recent experience and increasingly sharpened criteria of local farmers. Resistance to termites and other pests and the role of new plants as hosts of crop pests must be considered a priority criterion for species screening (Raintree et al., 1987).

- One of the outstanding gaps in the information is the mapping of land use and access, land cover and ecosystems types of the residents, in their own terms. Also conspicuously absent is the history of land cover, land use and land ownership and the condition

and management of soil, water and plant resource. Nor is there a history of drought, famine, crop pests and diseases or local responses. The same is true of the development of village infrastructure and people's perceptions of the trends in landscape development and resource management.

JOINT FOLLOW-UP OF THE TWO ETHNOECOLOGY STUDIES

Both studies converged increasingly toward a more integrated approach to pest control, species selection and land-use planning for the development of agroforestry systems in Kathama. One of the prerequisites for a more integrated ethnoecology research effort would be the development of a broader baseline of ecological information and the careful identification of topics for separate treatment (termites or indigenous plants), combined research (interaction of termites and indigenous plants) and systems-level research (termites and indigenous plants as parts of more complex systems).

A new round of informal surveys is now needed to provide a shared baseline on the community context for management of both pests and plant resources. This general ecological survey would clarify the community's own perception and provide an empirical basis for analyzing relationships among different land-use systems under existing and alternative arrangements of trees. The field surveys should combine informal interviews and mapping exercises with groups and individual specialists, as well as independent mapping by field researchers. The insights and information from this activity would apply to ecosystem-level questions in both the termite study (effect of bush land and tree distribution on termite on farms) and the plant study (management of woodlands, domestication of wild plants on the farm, distribution of trees within cropland, grazing land and in-between spaces).

Among the special-topics studies suggested by the work to date are the following.

Plant Domestication and Agroforestry

Formally screen "farmers' choice" indigenous and exotic species for agroforestry systems, on station and in the field (on farm and in the larger landscape) according to criteria identified in earlier trials by farmers.

Identify source areas/institutions and screen germplasm for farmer-selected indigenous and exotic species for agroforestry systems, according to the same criteria as above. Experiments could include on-station trials as well as field experiments on farm and in the larger landscape.

Test propagation and establishment techniques for selected indigenous and exotic species for agroforestry systems. Experiments could include both on-station and field experiments in nurseries, gardens, cropland, grazing land and wooded areas.

Test technology designs for “interlocking use” on shared-but-privately-owned grazing lands and woodlands on selected farms.

Termites

Observe tree and crop damage in the field under a wide range of conditions to determine if the sequential attack by different species of termites, observed by farmers, is obligatory or not.

Involve farmers in the collection of termites 1) when they attack plants, to document timing and extent of damage and to confirm which species caused the damage; and 2) when reproductives (elates) fly, to obtain exact information regarding nuptual flights of the different species of termites.

Construct and superimpose larger-scale maps of termite mounds on land-use maps to explore the relationship of termite abundance to land use, land cover and interfaces with surrounding land use and vegetation types.

The Interaction of Termites with Plant Domestication and Agroforestry

Conduct measurements of damage to naturally occurring and planted trees (stratified by age, land use and site type) to further document and clarify the resistance or susceptibility of various tree species to termite attack.

Collaborate with or follow farmers’ experiments on termite-control techniques such as using leaves from resistant trees as a mulch around seedlings to prevent termite attack and removing bush from farmland.

Initiate experiments with a few farm households to treat nursery beds, planted seedlings, wildlings, planting holes and small subplots (on cropland, grazing land, woodland and home compounds) with extracts and(or) mulches from repellant plants. The preparation of plant-based pesticides and repellants would be based on a combination of the best local knowledge and reports in the literature. Researchers could also conduct formal experiments under more controlled conditions (laboratory or research station).

Perhaps more crucial and certainly more accessible to the local community is the development of systems-level experiments by and for land users. The home garden and small grazing-land plots are the two niches most often chosen by farmers for trials of complex interventions. Both of these sites could accommodate a mix of interventions, including species and varietal screening, soil management (composting), water harvesting, fencing and pest control/pest resistance.

The nature of the research topics listed above has strong implications for the type of experiments needed as well as for individual research designs and the research-planning strategy. While there are some candidates for on-station trials, there is also a pressing need to conduct special-topic experiments on farm and in the field (bushland, woodland, etc).

Equally important and more difficult to design are the on-farm experiments with system-level testing by farmers of several related innovations, none of which will be useful to them without the other mutually supporting elements. These farmers could design their own experiments in consultation with outside and local researchers. An emphasis on small-scale, intensive, soil, water and pest-management techniques to support the new agroforestry practices would be required. The trials should employ ecological methods for characterization of systems and monitoring of changes in site quality and productivity. Evaluation by all local users of the site and its products should complement the assessments by researchers and farmer-owners.

A combination of simplified simulation models and visual models should be used to analyze and discuss the actual and projected performance of the new technologies. Sensitivity analysis of systems models based on such trials could help to clarify the relative importance and interaction of the various interventions (Upton, 1984; Rocheleau, 1984), including new species and spacing, pest-management techniques, water harvesting, composting and fencing.

The role of the local participants will be critical in all of the suggested follow-up activities. To be effective, continuing research with land users at Kathama must be based on shared information and understanding. At a minimum this will require preparation and distribution of an overall summary of results thus far and several short technical summaries in a language and format appropriate for participating community groups and individuals (Raintree et al., 1987). Using these materials and lessons-to-date as a point of departure, the success of the follow-up will rest firmly on the strength of the partnership between the community and the field-research team.

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Table 1. Candidate species for domestication in home gardens and homestead planning.

Leafy Vegetables		
1.	Kitulu	*Solanum nigrum*
2.	Kikungi	*Cucumis disaceus*
3.	Kiambatwe	*Cucumis aculeatus*
4.	Kikowe	*Commelina africana*
*	Kiw'oa	*Amaranthus hybridus*
Wild Fruits		
1.	Kitula	*Ximenia caffra*
2.	Kiua	*Sclerocarya birrea*
3.	Kithumula	*Tamarindus indica*
4.	Kitae	*Rubus pinnatus*
5.	Kikawe	*Carissa edulis*
6.	Kiva	*Pappea capensis*
7.	Kitoo	*Thespia danis*
8.	Kimuu	*Vitex payos*
9.	Kikavu	*Physalis peruviana*
**	Kilului	*Balenites aegyptiaca*
**	Kikuyu	*Ficus capensis*
Medicinal Plants		
1.	Mukenea	*Zanthoxylum chalybeum*
2.	Kikawa	*Carissa edulis*
3.	Muteta	*Strychnos henningsii*
4.	Kunani	*Ajuga remota*
5.	Mukalati	*Pavetta crassipes*
6.	Mukya	*Plumbego Zeylanica*
7.	Muthika	*Indigofera* spp.

* Already semidomesticated
** Popular but not yet rare enough; interest in future domestication.

Source: Data derived from Munyao, 1987; Mutiso, 1987; Rocheleau, 1985; Wachira, 1987; and Wanjohi, 1987.

Table 2. Frequency with which farmers associated Kikamba names with a particular genus of termite.

Genus	Kikamba names					
	Nthwa Mungasa	Mbaawa Mbaa-a	Mungumi Kathoa	Ngai Kikai	Ndulamatu	Kikii Kii
Macrotermes	25	3	1	--	1	--
Odontotermes	2	26	--	1	--	--
Microcerotermes	--	1	11	1	--	1
Pseudocanthotermes	--	3	1	7	--	--
Allodontotermes	1	1	--	--	18	--
Cubitermes	--	--	1	--	--	20
Pericapritermes	Collected in the study area but not described or named by farmers.					
Trinervitermes	Collected in the study area but not described or named by farmers.					
Amitermes	Collected in the study area but not described or named by farmers.					
Microtermes	Collected in the study area but not described or named by farmers.					

Table 3. Number of farmers attributing crop damage to a particular genus of termite.

Crop or plant	Termite Genus					
	Macro-termes	Odonto-termes	Micro-cero-termes	Allo-donto-termes	Cubi-termes	Pseudo-cantho-termes
Plants/organic matter consumed						
Humus					19	
Grasses	28	26	8	16	9	2
Annual crops						
Maize	27	25	11	13		8
Pigeon peas	26	25	9	16		10
Beans	22	20	8	5		3
Cowpeas	22	21				
Sorghum		8				
Perennial plants						
Solanum incunum	1	3	7	7		
Rhus spp.	11	9	10	6		
Cassava	12		6	2		
Guava	11	7		6		
Combretum spp. (*zeyhrii*, *collunum*)	22	22	5			
Lantana camara	20	22	8			
Eucalyptus spp.	8	13	9			
Citrus		20		3		
Leucaena leucocephala	22	20				
Jaccaranda		9	10			
Mango	16	17				
Sisal	6	7				
Terminalia brownii	8	8				
Acacia mellifora, *nilotica*, *tortilus*	13		8			
Vitex payo		7		4		
Tapiphyllum spp.	4					
Boscia angustifolia	4					
Commiphora spp.	9					
Cassia singueana				5		
Lonchocarpus eriocalyx				5		
Grewia bicolor	1					
Gravillea robusta	3					
Euphorbia spp.	11					

Table 4. Termite-control methods used by farmers.

Method	Impact on termites	No. of farmers
Destruction of nests/individuals		
1. Remove queen		19
2. Flood nest with rain water	20	
3. Pour hot water on nest		8
4. Use pesticides		19
5. Plow nest		11
Use of barriers/baits		
6. Use bricks, stones, sheet metal in construction		16
7. Burn lower portion of posts		5
8. Place sand or ashes around posts		19
9. Use creosote		17
10. Smear cow dung + water on posts		6
11. Smear cow fat around poles to attract ants		17
Manipulate part of land-use system		
12. Clear bush around cropland	Reduces no. and species	22
13. Construct terraces	Reduces no. and concentrates mounds	6
14. Rotate crops spatially or temporally	Reduces no.	13
15. Remove weeds, grasses, crop residues	Reduces no. and species	6
16. Place resistant plants on cropland	Reduces no. of attacks	3
17. Stop manuring land		3
18. Don’t plant near mounds		5
19. Convert grazing land to cropland	Reduces diversity	12

THE ORGANIZATION OF HOUSEHOLD LABOR IN A PHILIPPINE AGROFORESTRY SYSTEM

Mary Ann Pollisco-Botengan and Keith M. Moore[1]

INTRODUCTION

Approximately two-thirds of the population in the Philippines live in rural areas; a significant proportion, 14 million or one-fifth of the population, live in the uplands (Upland Multisectoral Policy Working Group, 1986). Due to overpopulation and limited productivity, the lowlands are no longer capable of providing all food requirements for the Filipinos. Furthermore, the fragile uplands will provide needed agricultural land because 1 million hectares of better quality lowlands will be lost to urban and industrial settlements in the years to come (Sajise, 1984). More and more people are forced to move to the uplands to eke out a living. What opportunities are available to these people? According to the Upland Multisectoral Policy Working Group (1986), there is a predominance of poverty in the uplands where the average annual household income is estimated to be $125.00 (P2,500.00), one-third of the household "food threshold income" of $375.00 (P7,500.00).

In light of these conditions, the Revised Forestry Code of the Philippines, through Presidential Decree 705 in 1975, emphasized the need to implement agroforestry as a development strategy that would produce more food as well as maintain the ecological balance of the land. Agroforestry is defined (Vergara, 1982) as "any sustainable land use system that maintains' or increases total yield by combining food crops with forest crops and/or livestock simultaneously, or sequentially, using management practices that are appropriate for the social and cultural characteristics of the local people and the economic and ecological conditions of the area."

Delbert Rice (1979) stated that the goals of upland agriculture, or agroforestry, must involve at least two factors: economic benefit for the farmers and the protection of the watershed areas from erosion and rapid runoff. In implementing such strategies, it must be realized that agroforestry (whether subsistence or commercial) requires intensive household labor inputs in different activities.

The objective of this study is to analyze the organization of household labor to meet the labor demands of an agroforestry system. An understanding of how household members relate with one another, other households and their sociocultural and biophysical worlds is required to analyze the organization of household labor. This study provides insights into the organization of household labor as agroforestry is introduced into communities in the highlands of northern Luzon.

[1]Graduate teaching associate, School of Renewable Natural Resources, University of Arizona; assistant professor, Department of Sociology, Oklahoma State University, Stillwater, OK, 74076, U.S.A.

Guyer (1981) suggested that the concept of the household implies a domestic unit that makes autonomous decisions about production and consumption. In Guyer's analysis of past literature on households, she noted that some approaches assumed that the household was a unit that controlled resources such as labor and made joint decisions on their allocation. Earlier, Barlett (1980) stated that "households have access to resources such as land, water, labor and information and have needs and goals such as a certain diet, education and other aspects of their standard of living."

A systems framework will be used to analyze various interdependent ecological and social components of agroforestry in a distinct forest ecosystem. Interaction and interdependence among these elements will be analyzed at the household level. Decisions on how to manage the land are made within a larger framework of the social, cultural, political, and economic structures. The household must also contend with perceptions and capabilities of its members in relation to other households, as well as to the environment. The sociocultural and biophysical systems define alternatives available to the household, especially in terms of how labor is allocated as it meets the demands of the agroforestry system.

Agroforestry is premised on meeting the diversified and pressing needs of the people, maintaining and improving the productivity of the land and eliminating disruptive on-site as well as off-site degradations (Revilla, 1983). A land-use practice such as agroforestry is sustainable when the land can continuously provide for a populace. How households implement sustainability is manifested by adjustments the household makes to its labor allocation. This is especially clear when all household activities are considered. It is presumed that the activities are perceived by the households to be necessary to maintain/sustain the household.

THE RESEARCH SITE

The agroforestry zone of Barangay Ambassador, Tublay, Benguet, was chosen as the research site. Barangay Ambassador was originally called "Boted," meaning bamboo, since the forest expanse was once filled with bamboo. Today the place is covered with pine forest, and there are ongoing, small-scale mining activities. Ambassador is about 18 km north of Baguio City and is situated along the Baguio-Bontoc road, making it accessible throughout the year. The innermost sitios (smallest geopolitical units of the barangay) are serviced by a single daily jeepney trip to and from Baguio City. It is the largest barangay in the municipality of Tublay, with a total land area of 1,152 ha and a population of 2,589 by 1980 estimates. It was accessible and relatively safe as a geopolitical unit when data were collected in 1984-1985.

Five sitios were selected for study, based on the implementation of an integrated social forestry program (ISFP) by the Bureau of Forest Development (BFD), where agroforestry is a prescribed strategy.

Various tools were used for gathering data. Researchers lived with 58 households in the study area. The research methodology included participant observation as well as informal interviews conducted while researchers were helping with household and farm chores. This strategy was important in establishing rapport and gaining the confidence of the household members. Key informants were also relied on to validate information. Consultants conducted a survey and analysis of the biophysical elements of the agroforestry system. For the most part, data gathered were subjected to qualitative analysis by means of case studies at the household level.

Biophysical Characteristics of Ambassador

The province of Benguet falls under climatic type 1: a distinct dry season from November to May and a rainy season during the rest of the year. Rainfall ranges from 1,800 mm to 5,800 mm per year, peaking in July and August. The average daily evaporation rates range from 3.4 mm to 3.8 mm. Atmospheric temperature ranges from a low mean of 12.2°C in December to 18°C during April, the warmest month. The average monthly relative humidity ranges from 68% in February to 82% in September.

The mountains in the research area contain copper and gold. From 1970 to 1981, portions of Ambassador were mined using the open-pit method. As a result, many landslides occurred along the Old Ambuklao Road. The research site falls within two subcatchment areas (Adonot and Bantay-Labey) of the Upper Agno River Basin. The Adonot subcatchment area has a mean slope of 64.88%. Bantay-Labey has a steeper mean slope of 71.75%. This subcatchment drains into the Ambuklao Lake, while the Adonot feeds its water into the Binga reservoir. Elevation ranges from 1,066.74 m to 1,828.71 m.

Outcrops of rocks are confined mainly to the ridge traversed by the Old Ambuklao Road. The rocks are fine-grained feldspathic quartzite meta-andesite and hornlende gabbro. Outcrops of gabbro also occur along the Baguio-Bontoc road. These parent materials are generally termed diorite. The soil is well drained, with silt loam as the dominant texture. The color varies from dark brown to yellowish red to light red within a profile. Soil samples collected at the sites where households planted their coffee seedlings, generally around the houses, are acidic with a 4.5 mean pH.

The dominant tree cover is a second growth of Benguet pine (*Pinus insularis* Endl.) forest. In the early part of 1960, reforestation was a major activity in many open lands that were created by logging operations. The nonforested and noncultivated areas are covered with a grass species called Runo (*Miscanthus sinensis*), while *Themeda triandra* and *Ischaenum* spp. are prevalent in the understory of Benguet pine stands, along with a few broadleaf species like Anabiong (*Trema orientale*), *Cleathrea* spp., Tibig (*Ficus* spp.) and *Melastroma polyanthium*. *Alnus maritima* is the common tree species planted along the road networks and property boundaries.

In previously cultivated areas, annual grass species are generally present (*Ageratum conyzoides*, *Bidens pilosa*, *Elucine indica*, *Ageratina*

adenophora, Eclipta alba, Miscanthus sinensis, and Sporobolu diander). Swards of Runo are mostly found in the abandoned/fallow areas.

The People of Ambassador

Of the 338 people in the 58 households included in the study, about 30% belonged to the 0-9 age group, closely followed by the 10-19 (24.8%), 20-29 (16.3%) and 30-39 (11.5%) age groups, with others sparsely distributed throughout the higher age brackets (Table 1). The mean number of living children born to a household was five, and the average household size was six. The majority of the respondents had received elementary schooling.

The total labor force among the 58 households was 266 (Table 2). Only those 7 years old and over who, in one way or another, were able to work and contribute to the household were included. Approximately one-fourth were seasonal laborers, followed closely by farm hands (21.4%), full-time farmers (17.7%), helpers in gold-panning activities (16.9%) and full-time gold panners (13.2%). A numerically significant portion of the labor force belonged to the 7-14 age bracket (30.5%), although a good 65.4% were between 15 and 65, the productive group. The mean annual household income was P9,195.53 ($459.78). Income was derived from full-time farming, full-time gold panning, seasonal labor, permanent employment and unearned income (pensions and money coming from relatives).

Close to 60% of the 58 households were migrants to Barangay Ambassador. Reasons for migrating to the area included family reasons (i.e., marrying somebody from the place) and job-related reasons, specifically when mining companies were still operating there. If there is a factor to which the immigration trend could be attributed, it would be the frontier status of the area and the lure of gold panning in the sitios.

Almost one-half (48.4%) of the households were members of the Kankana-ey ethnic group, followed by 41.4% Ibalois; the rest were evenly distributed among the Ifugaos, Kalingas and Ilocanos. It must be noted, though, that Barangay Ambassador is a geopolitical unit that has been traditionally identified as being predominantly Ibaloi.

GENERAL AREAS OF ACTIVITY IN BARANGAY AMBASSADOR

Subsistence Farming

The uma. Subsistence agricultural practices were found mostly in the uma. An uma is a traditional land clearing along gradually inclined mountain slopes or in backyards of households. These clearings were originally grass (cogon) lands converted to agricultural use. The method of clearing is called "lugam," which is the process of uprooting cogon and other grasses and shrubs growing in the area, at the same time loosening up the top soil for planting. Grasses and shrubs are dried and burned in the middle of the uma to minimize forest fires. The ashes are scattered over the uma and serve as fertilizer. Each respondent

household maintained an uma, the average size of which was 1/3 ha. Seldom does an uma exceed 1/2 ha.

During the dry season (November to May), the uma was planted with sweet potatoes if not left fallow. As the dry season ended, households prepared to plant the area with corn, legumes, squash, chayote and the omnipresent sweet potato. Harvest derived from the uma was mainly for household consumption. Surplus was either marketed or given to friends and relatives.

The uma was fenced to protect the crops from cattle. In many cases, fences served as boundary lines separating one uma from another. The most common type of material used for fencing was stalks from the reed, Runo. Runo was also used as a trellis for crops that needed support, such as snap beans.

Home gardens. The establishment and maintenance of home gardens were important activities in Barangay Ambassador. All households maintained a home garden that contained all the components of an agroforestry system: tree crops, agricultural crops, livestock and poultry.

The most commonly found tree crops along property boundaries were Alnus maritima (alnus) and Callistemon lanceolatum (bottle brush). Morus alba (mulberry), Albizzia falcataria, eucalyptus and Gmelina arborea were also found along property boundaries, but rarely. Most noticeable around the houses were fruit trees like Mangifera indica (mango), Persia americana (avocado) and Artocarpys heterophyllus (jackfruit/lanka). Of these trees, alnus, a nitrogen-fixing and fast-growing species, and eucalyptus had been introduced by the BFD in their reforestation efforts. The households started planting these tree species when it was explained that some agricultural crops, such as coffee, need shade trees for survival. These trees were also significant sources of fuelwood but were planted only when seedlings were available from the community nursery (which was supplied by BFD). Weeds were abundant in home gardens; weeding was performed by any household member who had the time.

Corn, beans and potatoes were grown in garden plots. Root crops, such as gabi, are integrated with other crops that are planted in backyards, such as coffee (arabica, excelsa and robusta), banana, pineapple, lemon grass, masaflora and napier. Napier had been recently introduced as fodder for some of the animals. Chayote was also planted in the backyards; the households used trees, Runo and(or) wires as trellis for the plants.

Regarding livestock and poultry production, households had an assortment of animals such as hogs, goats and poultry in their backyards. Again, these animals were raised purely for household consumption. The animals were generally slaughtered for certain rituals and ceremonies such as the "canao." One or two pigs or goats and a half-dozen or so poultry were found in these backyard gardens. The animals required much attention, especially the goats because they browse on any plant within their reach.

Pastoral activities. Only about 20% of the total household respondents had cattle, an average number of 4 and not more than 10 to a household. Historically, Ambassador used to be a cattle-raising township. Over time, however, large-scale cattle raising has ceased. In spite of this, communal pasturelands still exist. The majority of the land not developed for agricultural purposes and not owned by private individuals by virtue of either tax declarations or titles was regarded by the surrounding communities as communal pasturelands. All members of the community with a herd of cattle were allowed to use these tracts of land, provided they supervised their herds to prevent crop damage in adjoining agricultural lands.

Commercial Farming

For commercial farming in Ambassador, especially in the five sitios studied, there was at least one cropping season a year, during the wet months. A typical commercial farmer owned an average of 0.25 ha dedicated to commercial purposes and tended to at least one uma. Of the 58 households in the study, 16 were engaged in commercial farming; of these 16, 5 had irrigated farm lands, making a whole year of cropping possible. The remaining 11 farms grew rainfed crops. Commercial farmers with extensive irrigation systems diversified their cropping patterns.

Agricultural lands for commercial purposes were generally found in terraced areas. Terracing was a major land-preparation activity, characterized by carving the mountain slopes in stairway fashion to control soil erosion and to facilitate more extensive and sophisticated farming techniques. This was particularly true in one sitio (Nalseb), where terraced lands were supported by large and extensive irrigation systems. This allowed the farmers to plant cash crops even during the dry season. Unirrigated terraced lands had to rely on rainfall for moisture; hence they were mostly planted to crops requiring less moisture, like sweet potato, during the dry season. In many cases, farmers simply allowed their farms to fallow during the dry months.

The cash crops produced by these farms were mostly subtropical: snap beans (baguio beans), snow peas (chicharo), Chinese cabbage (wombok), carrots, cabbage and radishes. Rice was also planted, especially in Labey, where the climate was warmer and there was sufficient irrigation. Traditional rice seed varieties, which took 4 to 5 months to mature, were used by the farmers.

Mining

Barangay Ambassador claims a total area of 848 ha of mineral-rich land. The Bureau of Mines estimates that it has an ore deposit of 33 million metric tons. Over the past decade, Baguio Gold Corporation had operated mining concessions but stopped in 1982 because of low copper prices in the world market. The main mineral deposits are copper, gold and silver. When mining operations ceased, the abandoned mining claims were taken over by the local populace, particularly by those living in Tabeyo, Manuyod and Sapuan (sitios included in the study).

Gold panning was the main activity in these sitios and was pursued all year. Unlike vegetable growing, required cash outlays were minimal. It was a labor-intensive effort, but the labor requirements were primarily supplied by household members. The first of several steps was gathering mine tailings or soil combined with mud and rocks. Next, these were ground to a granular consistency until they were ready for filtering. Filtering was repeated several times to bring out yellowish stones/pebbles/sand/nuggets, which were melted and shaped for sale. Cash expenditures were basically for gasoline for the bore mill -- it took 1 liter to grind a sack of soil. Miners who went deep into adits required timber from the nearby pine forest for support in the mine tunnels.

Employment

Approximately 30% of the total household members were employed outside the household as teachers, storekeepers, seasonal laborers, a blacksmith, a heavy equipment operator and the like. "Employment" here means that they were self-employed or were employed by agencies or other people, in that the employed person earned a cash income for the household through a wage-labor type of relationship. Those who practiced full-time farming or gold panning, or a combination of gold panning and farming, have not been included in this category; neither have household members who worked only part-time on their respective household farms.

Seasonal labor. About 23% of all household members worked as seasonal laborers, either as BFD laborers or contract farm workers. Farm workers were employed for at least 6 person-days per cropping season by commercial farmers. On the other hand, BFD laborers were employed on a rotation basis such that all laborers worked with BFD for 16 consecutive days then waited for their turn again while others worked. While waiting for the work season, the laborers returned to their household farm and helped out. Seasonal laborers are sometimes lucky enough to work for commercial farmers who simultaneously produced several crops during the season or who produced throughout the entire year.

Permanent employment. A negligible 1.5% of the total respondent household members were permanently employed as teachers, a heavy machinery operator and a blacksmith. This group had regular working hours during the day on specific days of the week. Most of these people were employed outside of the community, and the commuting time was long. The skilled workers commuted on weekends, while the teachers commuted every school day.

Education-related Activities

Close to one-third of household members were in school. Elementary schooling was available within the communities while secondary education required commuting. Most of those going to school were in elementary and secondary school, after which they dropped out. Even if the elementary school was found within the locality, the average hike for the school children to and from school was 3 km. As for college education, those interested had to travel to Baguio City and return to

the sitio on weekends. Of course, this group (college students) was the smallest.

INTEGRATED ANALYSIS OF HOUSEHOLD LABOR ALLOCATION: THREE CASES

This section analyzes how three households typically allocate labor to ensure their survival. The three representative households were selected as typical of the dominant activities found in the locality: gold panning, subsistence farming and commercial farming.

Case 1: Gold Panning

Ramon and Arsenia Wakit (not their real names) are in their early 30s and have two boys and a girl whose ages range from 2 to 8. Both Ramon and Arsenia attended elementary school. Their eldest son is in the first grade, the second is not yet of schooling age (5 years), and the youngest is a girl.

The Wakits own a 0.28-ha uma planted to subsistence crops such as sweet potatoes and other rootcrops. The uma is tended by Arsenia when her husband does not need assistance in gold-panning activities. Arsenia works in the uma and home garden with her youngest child kept in a blanket tied around her torso.

Ramon is gold panner for most of the year. He takes time off only to take the gold to the market. Most of what he earns from gold panning is spent on weekend bashes with friends in the nearby city. He gives part of his earnings to his wife for household needs, and occasionally they share their bounty with their neighbors by holding a feast (canao). The process of gold panning is tedious but does not require many laborers. Only when a gold strike is near does Ramon enjoin his wife and sons to help him speed up the task.

The younger boys run errands for their parents, be it for the house, field or mine. At times, the little boys are seen hauling ore-laden earth from one place to another. Other times, though, they are in the home garden chasing stray animals or feeding the chicken, dog and pig. Fuelwood is gathered by all members of the household.

Case 2: Subsistence Farming

Domingo and Luisa Becka (not their real names) are in their late 30s, and have been married for about 20 years. They have three boys and two girls whose ages range from 4 to 16. Domingo attended school through the third grade; Luisa attended through the sixth. The eldest boy, 16 years, is in high school and studies in Acop; he takes the daily single jeepney ride from and to the sitio. The second child is a 13-year-old girl who is in the sixth grade and walks to school (2 km away) every school day with her 10-year-old brother and 7-year-old sister. The youngest boy is 4.

The Beckas own an uma (0.39 ha) and a home garden. Luisa tends to both. When the children come home from school, they help their mother. Also,

every morning the whole household gets up early enough (4:30 a.m.) to do their share of the household chores before they all go their separate ways for the day (6:30 a.m.). Domingo, who is a seasonal laborer for a commercial farmer, proceeds to the garden to do the chores. They have two goats, a rooster and four hens, a dog and a pig. The pig is kept in a pen next to the latrine, which is about 5 m from the house. The eldest boy helps Luisa by chopping the firewood that is needed for the day while Luisa prepares breakfast. The eldest girl starts cleaning the house and prepares the clothes that her other brothers and sister will wear that day. The three younger ones get up a little later but likewise assist the older members as they are needed.

Domingo has irregular working hours. He is most busy during the onset of the rainy season when he is preparing the land for the farmers for whom he works. Sometimes, after working with one farmer, he is called upon by another farmer from the area. But then again, sometimes he does not have work and spends time developing his own uma and home garden. Domingo takes pains to care for the coffee plants, harvesting the nuts and drying and roasting them. The coffee he produces is for a select group of regular buyers. The surplus is for household consumption. When he is working on other farms, his wife takes over the coffee business.

Case 3: Commercial Farming

Kigas and Tubelia Wasi (not their real names) are in their mid-40s and have two boys and two girls whose ages range from 13 to 25. The older two are already married and have families of their own. The two younger ones, aged 16 (male) and 13 (female), are both in high school and, like the Becka boy, take the daily single jeepney trip to and from Acop.

The Wasis own 1 ha of irrigated terraced land for commercial purposes. They produce snap beans alternated with rice. The Wasis found out that they produce better rice after snap beans. This is primarily because snap beans are leguminous and so fix nitrogen and provide nutrients to the soil. Beans are grown the first half of the year, and rice is grown the second half.

Since the two remaining children are in school from June to April except during weekends and holidays, the Wasis hire an average of four laborers throughout the year, at an average of 12 days annually. Kigas Wasi retains at least one laborer to work with him throughout the whole year to maintain the farm. When the kids are not in school, they help out on the farm or in the uma (0.29 ha), depending on what and where the demand is at the time.

Tubelia likewise helps out on the farm but is more visible working with the uma and home garden. However, when land-preparation time comes for both the commercial farm and the uma, the whole family helps out. The kids do so on weekends and holidays. Seasonal laborers are hired to help prepare and maintain the terraced lands. At least one laborer assists Kigas in maintaining the terraced land and crops. The snap beans are harvested by the family and the retained laborer, because by then the kids are out of school.

The home garden is cared for by the whole household during anybody's spare time, i.e., an hour every 2 to 3 days. The Wasi home garden is abundant with fruit trees and crops, arranged arbitrarily. A dozen poultry and a dog freely roam the garden. Two pigs are caged on the premises. It is only these animals that require regular tending, and the kids take care of this before they go to school and when they get back late in the afternoon. Fuelwood is gathered by all household members. Most often someone gathers the wood in the course of conducting routine activities, as when in the uma.

CONCLUSION

This particular agroforestry system is complex in terms of household activities. Several observations are worthy of note:

1. The labor allocations within households are not fixed in terms of sex. There are occasional shifts in responsibilities among household members. Labor allocation is basically dependent on the demand and nature of the job. Women generally undertake work on the uma, household chores and home garden maintenance. However, they are also heavily relied upon to share the workload in gold panning, seasonal labor and sometimes full-time farming.

2. The younger members of the household spend most of their time with education-related activities. They assist in farming, gold panning and household work when they are out of school. Members from 15 to 65 constitute the major labor force of the household. Participation in activities that sustain the household is not fixed by age. As soon as the children are physically able to do their share, even in the smallest possible way, they are expected to work. This is the same with the senior citizens -- as long as they are able to work in the farms or help with household chores, they are still part of the work force.

3. The only biophysical constraint is the combination of the relatively high rainfall and steep slope, which produces landslides and soil erosion. This means that greater efforts are necessary not only to prepare the land for farming but also to maintain the terraces and the uma.

4. Labor activities are concentrated within the barangay itself. The percentage of labor expected by the community is negligible.

Many of the activities studied do not require large amounts of labor. Even the maintenance of the home garden does not require much labor. Penafiel (1986) states that agroforestry gardens do not require much labor or attention because everything is handled by whoever has some free time. Nevertheless, land preparation and planting require much labor. There is an adequate labor force willing to undertake these tasks for the survival of the household as demanded by the agroforestry system. This is especially so since most of the people are not trained for work outside of the community. However, it is evident that they

have high aspirations for their children since most if not all school-age children are in school.

The labor needed to maintain and(or) develop this particular agroforestry system is locally available. In fact, there is more labor than is needed for the agroforestry system since people continuously open or clear the land through such activities as gold panning and subsistence agriculture. In due time, the umas are converted to commercial farms, especially in the case of enterprising farmers. Or sometimes, farmers presently engaged in large-scale vegetable production require more land for expansion. Future agroforestry-development programs, therefore, must be capable of providing alternative activities for areas like the research site where there is excess labor. Otherwise, more areas in this mountain region will give way to intensive agricultural production that destroys the ecological balance.

Agroforestry in general can be an alternative solution to the worsening ecological and economic situation of a people. For agroforestry to be a successful development program, labor demand and supply in an intended area for implementation should be fully examined. Agroforestry requires a balance between the biophysical and sociocultural worlds, so that it may achieve its goal — to sustain both the land and its resources, and the households.

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Table 1. Respondent households by age and sex.

	Males		Females		Total	
Age group	N	%	N	%	N	%
0-9	48.0	26.7	52.0	32.9	100.0	29.6
10-19	47.0	26.1	37.0	23.4	84.0	24.8
20-29	30.0	16.7	25.0	15.8	55.0	16.3
30-39	20.0	11.1	19.0	12.0	39.0	11.5
40-49	14.0	7.8	14.0	8.7	28.0	8.2
50-59	12.0	6.7	6.0	3.8	18.0	5.3
60-69	6.0	3.3	2.0	1.3	8.0	2.5
70-79	1.0	0.5	1.0	0.6	2.0	0.5
80 +	1.0	0.5	0.0	1.1	1.0	0.3
NS	1.0	0.5	2.0	1.3	3.0	1.0
Total	180.0	53.3	159.0	46.7	338.0	100.0

Table 2. Labor force of respondent households by age, sex and primary work role.

Work role	7-14		15-65		66+		Subtotal		Total	
	M	F	M	F	M	F	M	F	#	%
*sea. labor	11	7	25	19			36	26	63	23.3
farm hand	13	26	6	9		3	19	38	57	21.4
*f/t farming			15	27	3	2	18	29	47	17.7
*ass. mining	15	9	15	6			30	15	45	16.9
*f/t mining			24	8	3		27	8	35	13.2
*farm/mine			9	5			9	5	14	5.3
*perm. emp.			2	2			2	2	4	1.5
others			1	1			1	1	2	0.7
Subtotal	39	42	97	77	6	5	142	124		
Total	81		174		11		266		100	

*sea. labor = seasonal labor
f/t farming = full-time farming
ass. mining = assists in mining activities
f/t mining = full-time mining
perm. emp. = permanently employed

FIELD STUDIES ON GROWTH PERFORMANCE OF ALLEY SHRUBS IN THE HIGHLAND REGION OF RWANDA

Charles F. Yamoah, Ron K. Grosz and Egide Nizeyimana[1]

INTRODUCTION

Rwanda's highlands range between 1,500 m and 2,500 m (ISNAR, 1983). Slopes on most farmlands exceed 30% with a high farmer-to-land ratio. Rainfall combined with steep denuded slopes results in soil loss, run-off and soil fertility degradation. Existing erosion control measures, e.g., terracing and grasses planted along contours, have generally fallen into disrepair. Thus, soil productivity continues to decline in this densely populated region.

Inter-row cropping of leguminous trees with food crops, i.e., alley cropping, is a practice recommended for control of soil erosion on sloping lands (Young, 1984; ISNAR, 1983). Specifically, Zimmerman (1986) and Ross (1984) proposed such an approach for solving land degradation problems in Haiti and Indonesia under conditions analogous to the highland regions of Rwanda.

Alley cropping can also provide fuelwood and forages in addition to erosion control (Robins, 1985). Farmers' acceptance is anticipated because alley cropping is similar to the natural bush fallow system.

Two research needs must be addressed to implement alley cropping in Rwanda. First, shrubs suited to the local environment need to be identified, and, second, management practices to enhance the survival and growth of agroforestry shrubs need to be developed. This paper reports on the following:

- the growth performance of *Sesbania sesban* (Sesbania) intercropped with peas, beans, potatoes and wheat in two agroecological zones

- the growth performance of Sesbania, *Calliandra calothyrsus* (Calliandra), *Leucaena leucocephala* (Leucaena) and *Markhamia lutea* (Markhamia) as affected by lime and manure application

- the growth performance of Sesbania and Leucaena in selected microecozones

- farmers' involvement in the research process

[1]Rwanda Farming Systems Research Program (FSRP), B.P. 625, Kigali, Rwanda; Formerly Rwanda FSRP, currently 1833 N. Quesada, Arlington, VA 22205, U.S.A.; Formerly Rwanda FSRP, currently c/o Thomas J. Bicki, Dept. of Agronomy, University of Illinois, Urbana, IL 61801, U.S.A.

BACKGROUND AND METHODOLOGY

The research was conducted in the operational zone of the Farming Systems Improvement Project (FSIP) in the northeastern highlands of Rwanda. Two agroecological zones, the Buberuka highlands and the central plateau, are delineated in this area (ISAR, 1985). Information on these zones is summarized in Table 1. The three studies used different protocols.

Study One

The objective of the first study was to determine the effect of beans, peas, wheat and potatoes grown in association with Sesbania on shrub growth. The chosen food crops dominate local cropping systems, and information from the project's exploratory surveys indicated that leguminous shrubs have poorer growth performance when intercropped with grain legumes, such as peas and beans, instead of with cereals.

Widespread acceptance of agroforestry depends on the ease of establishment and subsequent management of the companion shrubs. The easiest and cheapest way of promoting the system to farmers is to demonstrate interplanting the shrubs with common food crops. The primary aim of this study was to identify food crops and shrub combinations that would be compatible during the establishment phase. A secondary objective was to investigate shrub adaptability in the two major agroecological zones. The third objective was to obtain baseline yield data for future evaluations.

At each location eight rows of 4-month-old Sesbania seedlings were planted 0.5 m apart within rows. The rows were 40 m long, and alley-ways varied between 2 m and 8 m in width. The 40-m long block of Sesbania was divided into 5 plots. Food crops (peas, beans, potatoes and wheat) and the control treatments were assigned randomly to the plots and repeated twice. Five shrubs were tagged in each plot, and heights were measured at monthly intervals until the food crops were harvested. A hundred plants per location were sampled 1 year after establishment for the biomass and height assessments.

Study Two

This study arose from observations made during the project's exploratory surveys. In some locations in Rwanda, particularly in the south with its relatively low altitude and warm environment, most leguminous shrubs including Leucaena and Calliandra are easily grown. However, these shrubs are seldom found in the northeastern highlands. This supports the literature that Leucaena and some leguminous shrubs do not grow well at high altitudes. In one project location with an altitude of 2,000 m, Leucaena was discovered to exhibit good growth performance. Further enquiry revealed the site has been enriched with manure. This led to the study question, "Could the application of manure be used to offset the negative altitudinal effect on the growth of Leucaena and other leguminous shrubs?" Soils in the project area are strongly acidic (pH 3.5-5), a potential limitation on the legume performance. The second question addressed was, "Could moderate application of lime mined from a

local source enhance the growth rate of the leguminous shrubs?" During the first season in 1986, four leguminous shrubs, Sesbania, Calliandra, Leucaena and Markhamia, planted at 0.5 m by 4 m within and between rows, respectively, formed the main plots. Manure at the rates of 0, 2.5, 5.0 and 10.0 t/ha were assigned to the subplots. The food crop planted was potatoes. The length of each row of shrub was 30 m, and there were two repetitions. Treatments were slightly modified during the second growing season as follows: the four leguminous shrubs constituted the main plots; subplots were lime rated at 0 and 0.75 t/ha, and sub-subplots were manure dressings at 0, 5.0 and 10.0 t/ha. There were two replications, and the test crop were maize. Five shrubs in each sub-subplot were tagged and measured at monthly intervals for the two growing seasons.

Study Three

Following a farmer field day (Yamoah and Grosz, 1986), 15 sites covering selected microecozones in the project area were chosen for multilocational testing of Sesbania and Leucaena. The trials were planted in farmers' fields with the following design. The length of rows along the contour was 20 m, and the spacing of shrubs within rows was 0.5 m. Spacing of shrubs between rows is determined by the formula D = 100/%S (Young, personal communication) where D = alley width (m) and S = % slope. The shrubs were planted in October 1986, and growth measurements were taken from January to April 1987.

RESULTS AND DISCUSSIONS

Food Crop Yields

The food crop yields at both sites were poor and reflected the low soil productivity of the experimental plots (Table 1). Crop yields on the whole were higher at the Buberuka region than at the central plateau area. The ravaging of the pea and wheat plots by birds at the central plateau site made statistical analysis on the yield data meaningless. That not withstanding, the yield gaps for wheat, potatoes and peas were large for the two sites. For instance, yields were 44 kg/ha (beans), 662 kg/ha (peas), 1,018 kg/ha (wheat) and 9,375 kg/ha (potatoes) at the Buberuka highlands as opposed to the central region where less than half the above yields were recorded. Average yields for the same food crops elsewhere in the country are 1,000 kg/ha (beans), 1,900 kg/ha (wheat), and 15,000 kg/ha (potatoes) (MINAGRI, 1985).

The following interferences can be drawn from these preliminary results: potatoes and wheat are more adaptable to the high altitude cold environment (Buberuka highlands) than the relatively low altitude warm central plateau environment. In terms of higher returns from invested labor, farmers in both regions can benefit by planting potatoes instead of beans on the poor soils. The fact that beans exhibited the highest sensitivity to low soil fertility may indicate farmers' preference to use their limited quantities of manure on beans rather than on their potato fields. The shrub did not adversely affect any of the food crops at this initial stage.

Performance of Shrubs

The growth performance of Sesbania as affected by the associated food crops is shown in Fig. 1. In general, the initial growth performance of the shrub at the central plateau region was slightly better than in the Buberuka zone, but the difference in growth between the two sites was not significant.

The growth at both sites started slowly during the first two months after establishment and increased significantly thereafter when adequate roots might have been formed and established in the soil. The accelerated growth rate following root establishment was observed even during the dry season (June and July). If this proves to be the normal growth pattern, it would be advantageous with respect to producing dry season fodder as well as organic material and nitrogen for the subsequent seasons' crops.

The effect of food crops on the growth of the shrub was significant in some cases. Beans had the greatest effect on shrub growth followed by potatoes, wheat and peas. Whereas the height of the shrub in the bean and potato plots differed significantly from those in the pea plot, those of the wheat and pea were not significantly different. The shrubs planted alone performed better than most planted on the food crop sites, but acute land scarcity in the project area will make this option unacceptable to farmers.

In both test locations, shrub growth was retarded in the plots with peas. Additional testing should be done to confirm these preliminary results and to determine whether the effect is present in other than the establishment phase. Beans, on the other hand, seem to have a positive effect on the growth of Sesbania in the central plateau region, which contradicts an earlier observation made at the Buberuka highlands (Graf and Yamoah, unpublished). This implies that in the low altitude, high rainfall central plateau area, a good establishment of Sesbania can be obtained by intercropping with beans instead of peas, potatoes or wheat. For the Buberuka region, the initial companion food crop is a matter of choice (keeping in mind the possibility that peas might retard shrub growth).

Figures 2a and 2b show the frequency distribution of biomass and height for Sesbania in the two major ecozones. Biomass production in the Buberuka region was 3.4 kg per plant compared to 2.8 kg in the central plateau. Sixteen percent of the shrubs yielded between 4.4 and 6.4 kg/plant fresh matter (Fig. 2a). The mean fresh matter yield per plant in this region was 3.4 kg and is equivalent to 8,500 kg dry matter/ha for a 0.5 m x 4.0 m alley formation having a density of 5,000 plants/ha. Biomass in this context comprises the woody stem, small twigs and leaves. Therefore, in effect the amount of dry organic material actually incorporated into the soil is around 3,000 kg/ha. Dry matter yields from Gliricida sepium, Cassia siamea and Flemingia congesta, pruned 2 years after establishment in Nigeria were 3,120 kg/ha, 10,666 kg/ha and 1,955 kg/ha for the respective shrubs (Yamoah et al., 1986). Leaf dry weights of 2,300 kg/ha and 2,467 kg/ha for Gliricidia and Leucaena, respectively, using an alley spacing of 0.5 m x 2 m after a

year's growth, have also been reported at the International Institute of Tropical Agriculture (IITA, 1979). At the central plateau region, however, 72% of the shrub gave fresh matter yield of < 3.4 kg/plant, 25% gave between 3.4 and 4.4 kg/plant, 1% gave between 4.4 to 5.4 kg/plant, and none yielded above 5.4 kg/plant (Fig. 2a). The relatively low fresh matter production in this region could be attributed to the poor soils (Table 1). For poor soils at the central plateau with percentage base saturation of 17% and pH of 4.3, application of manure and lime may be necessary to enhance the growth rates of the shrubs in the establishment phase. On a per-hectare basis, the dry leaf weight in this zone comes to 2,100 kg, which compares favorably with the data for Gliricidia and Leucaena cited in IITA (1979) above. With respect to height of shrub, 86% of the plants at the Buberuka highlands attained 3.4 m or more after 1 year whereas only 5% of the shrubs in the central plateau region reached the same height. Ninety-four percent of the shrubs in the latter region attained a height of less than 3.4 m (Fig. 2b). The initial growth rate of the shrub in this environment, however, was slightly better than those in the Buberuka region (Fig. 1). Mean heights for the shrub in Buberuka and central plateau regions are 4.1 m and 2.7 m, respectively.

Application of moderate quantities of manure increased the growth rates of all the alley shrubs that were tested (Fig. 3). The increase, however, was not significant in all cases. A large increase of about 20% was registered with Calliandra and Sesbania. Five tons of manure per hectare appears to be the optimum level of application for all the shrubs, but growth was not significantly different from the use of 2.5 t/ha. Hill (1970) found a better growth rate of Leucaena when fertilizer nitrogen was applied at the establishment stage. Total heights of the shrubs at 3 and 4 months after planting (MAP) are depicted in Table 2. There were significant differences among some of the shrubs. This was particularly noted between Sesbania and Leucaena and between Markhamia and Calliandra. Sesbania exhibited the fastest growth, followed by Leucaena. Markhamia, native to the region, showed the poorest growth performance. Table 3 shows the height of the alley shrubs as affected by lime and manure. Lime application as low as 0.75 t/ha increased the growth of all the shrubs. Significant differences among the heights of the shrubs persisted throughout the 8-month period. The progressive difference in height between Calliandra and Markhamia is interesting. Wide differences were observed among the heights of the shrubs at 8 MAP. The ranges are as follows: Sesbania, 3.56 m to 4.24 m; Leucaena, 1.48 m to 2.14 m; Calliandra, 1.39 m to 1.64 m; and Markhamia, 0.35 m to 0.49 m (Table 3). The term "lime response index" (LRI) is used to capture the real effect of liming on the growth rates of the shrubs (Fig. 4). Lime response index is simply the difference in relative increase in growth rates of the shrubs with and without lime application and is computed as follows:

$$LRI = GL - GLo$$

where GL = the mean relative increase in growth (RIG) of the shrubs in the plots where lime was applied

GLo = the RIG of the shrubs in the plots without lime treatment between 3 and 8 MAP in the field

Lime response index decreased with the quantity of manure applied in the case of Leucaena, but no definite trend was observed with the other shrubs. Relative increase in growth was highest for Calliandra, followed by Sesbania. Markhamia showed the slowest growth rate. Calliandra and Leucaena were most responsive to lime application with LRI of 0.88. Sesbania was the shrub least responsive to liming with LRI of 0.36 (Fig, 4, top section). The results imply that Sesbania is more tolerant to the acid soils generally encountered in the project area than Leucaena, Calliandra or Markhamia. The growth performance of Sesbania and Leucaena in selected microecozones is portrayed in Fig. 5a and 5b, respectively.

There are significant differences in growth of Sesbania among some of the sites (Fig. 5a). For example, the height of Sesbania at site 7 in April 1987 was more than twice the height of the same species at site 1 for the same period.

Sites 1, 2 and 3 belong to central plateau and sites 4, 5, 6 and 7 to the Buberuka highland region. Within the same major agroecological zone, the shrub performed differently depending on the microecozones where the shrub is planted. General observation revealed better plant growth in the bottom soils than the upper and middle slope areas. As evidence in support of this is the growth differences among the shrubs at site 2 (bottom soil) and sites 1 and 3 (upper to middle slope soils) (Fig. 5a). The exceptional growth rate of the shrub at site 7 may partly be due to the relatively rich bottom soils on which the shrub was planted and partly attributed to the nature of the soils in the area. The soils at site 7 border the volcanic soils in the project area that are classified in the USDA system as Andepts (ISAR, 1985). These are generally recognized as more fertile soils than the intensively used Ultisols on which shrubs in sites 4, 5, and 6 were placed.

In general, Sesbania out-performed Leucaena in terms of growth rate. The best growth rates for Leucaena were noted at site 1 (central plateau) on bottom soils and site 5 (Buberuka highland), which is near the same volcanic soil as site 7 for Sesbania. Average height for a 5-month Leucaena in Rwanda is 80 cm. None of the farmers applied manure or fertilizer to the fields on which the shrubs were planted. The average growth rates (AGR) in cm/month for the shrubs at the sites are indicated above the bar graphs of Fig. 5a and 5b. Clearly, Sesbania exhibits faster growth rate than Leucaena. To illustrate, Sesbania had an average growth rate of 62.2 cm/month as opposed to 27.4 cm/month for Leucaena at the same location. The AGRs for the shrubs on the valley bottom soils (sites 2 and 7 for Sesbania and sites 1 and 5 for Leucaena) are superior to those for their counterparts on the upland and mid-slope soils (Fig. 5a and 5b). Both Leucaena and Sesbania showed significant growth over time, and these growth rates were consistently better on the pedologically favored sites 7 and 2 for Sesbania and 1 and 5 for Leucaena.

FARMERS' INVOLVEMENT IN RESEARCH

Farmers' participation in the overall agroforestry research activities is best visualized in Fig. 6. This tree diagram bears three major components: component 1 -- information gathering and analysis (diagnosis); component 2 -- technology testing and farmer orientation; and component 3 -- farmer training.

Technology testing comprised two stages:

Stage 1. The purpose of this stage was to ascertain the biological feasibility of selected agroforestry species under the principal agroclimatic zones in the project area. Three sites were chosen for the start-up phase. The three sites were 1) the Buberuka highlands, 2) the central plateau, and 3) the Rugezi swamp. The last site falls on a Histosol. Details of protocols were as reported in studies 1 and 2 above. During a field day, farmers were made aware of the proposed agroforestry interventions, and cooperating farmers for stage 2 were then chosen to continue the research process (Yamoah and Grosz, 1986).

Stage 2. Participating farmers picked from stage 1 were plotted on the soils and land-use map of the project area to ensure a fair representation of the observed micro agroecological zones. In all, 15 sites were used for the second stage multilocational testing. The shrubs under experimentation were Leucaena, Calliandra, Sesbania and Markhamia. Lack of adequate planting materials and initial slow growth rates of Markhamia and Calliandra limited their testing to the Buberuka highlands and central plateau regions only. Informal dialogue with these cooperating farmers graded the value of alley cropping in the following order: supply of stakes > production of fuelwood > provision of fodder > erosion control device > soil fertility improver.

To accomplish farmer training, a hands-on participatory workshop was held for some of the farmers who had field trials on their land during the 1986/1987 cropping season. The extension workers responsible for the administrative sectors in which these trials were located were also invited to the workshop. Farmers were trained in the following aspects of agroforestry:

- small-scale nursery establishment using local materials (KWDP, 1985)
- establishment of alley cropping on sloping lands using a procedure akin to the practice of ICRAF field station at Machakos, Kenya
- pruning methods and the use of pruned materials as green manure and as support poles for climbing beans
- recordkeeping of growth of shrubs and rainfall as well as soil sampling techniques and yield assessment

After the workshop, each farmer-researcher was asked to install five additional on-farm trials with neighboring farmers in collaboration with their extension worker and to monitor and evaluate these trials. Their

task as research field assistants involved coordinating trials, planting follow-up and evaluation under the guidance and supervision of their extension workers. Thus, both farmers and extension cadre were intimately involved in the research and extension process.

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Table 1. Some environmental characteristics of the two major ecozones in the Farming Systems Improvement Project (FSIP) area.

Characteristics	Buberuka highland	Central plateau
Altitude (m)	1,800-2,650	1,500-1,700
Rainfall (mm)	1,564	1,166
Temperature (°C)	15.1-16.7	17-22
Soil pH	4.8	4.3
Total N (%)	0.38	0.15
% organic carbon	3.5	1.4
Clay (%)	60.8	36.1
CEC (meq/100 g)	22.8	15.7
Base saturation (%)	47.4	16.8

Table 2. Effect of manure on growth of alley shrubs.

Shrub	Manure	Height 3MAP[1]	Height 4MAP
	(t/ha)	--------cm--------	
Leucaena	0.0	47.7	57.8
	2.5	56.8	69.2
	5.0	57.7	67.4
	10.0	52.3	63.8
Markhamia	0.0	14.8	15.6
	2.5	16.5	17.3
	5.0	15.6	18.4
	10.0	17.5	16.7
Calliandra	0.0	14.6	19.5
	2.5	17.5	21.5
	5.0	17.8	26.9
	10.0	13.8	20.7
Sesbania	0.0	83.5	110.8
	2.5	81.3	119.0
	5.0	75.5	112.5
	10.0	81.8	122.8
LSD (0.05) Shrubs with same manure		13.6	38.05

[1] MAP = Months after planting on the field.

Table 3. Effect of lime and manure application on growth of alley shrubs.

Shrub	Lime	Manure	Height			
			5MAP[1]	6MAP	7MAP	8MAP
	(t/ha)	(t/ha)	cm			
Leucaena	0	0.0	58.3	86.7	125.2	180.0
		5.0	68.6	107.9	120.3	179.0
		10.0	62.0	89.4	125.0	148.0
	0.75	0.0	81.9	132.5	135.0	194.0
		5.0	72.0	107.4	125.3	214.0
		10.0	77.1	112.2	143.0	186.0
Markhamia	0	0.0	17.2	26.5	31.2	43.0
		5.0	19.4	27.7	32.3	45.3
		10.0	17.4	25.9	29.3	34.8
	0.75	0.0	26.5	36.7	37.1	47.5
		5.0	16.5	35.1	36.3	49.3
		10.0	21.3	34.3	35.3	48.8
Calliandra	0	0.0	25.1	43.6	78.8	141.0
		5.0	26.1	57.5	100.0	139.0
		10.0	25.5	45.3	75.0	141.0
	0.75	0.0	36.1	60.1	108.5	147.0
		5.0	33.0	61.3	104.5	153.0
		10.0	34.4	50.6	107.5	164.4
Sesbania	0	0.0	127.0	197.0	318.0	386.0
		5.0	136.2	217.0	336.0	390.0
		10.0	112.3	110.0	323.0	356.0
	0.75	0.0	221.0	292.0	383.0	402.0
		5.0	167.5	274.0	360.0	392.0
		10.0	199.5	276.5	376.0	424.0
LSD (0.05): Shrubs		-	93.0	48.0	93.1	63.4
Shrub x Lime			17.8	NS	NS	NS
Lime x Manure			9.8	10.3	9.5	10.6

[1] MAP = Months after planting on the field.

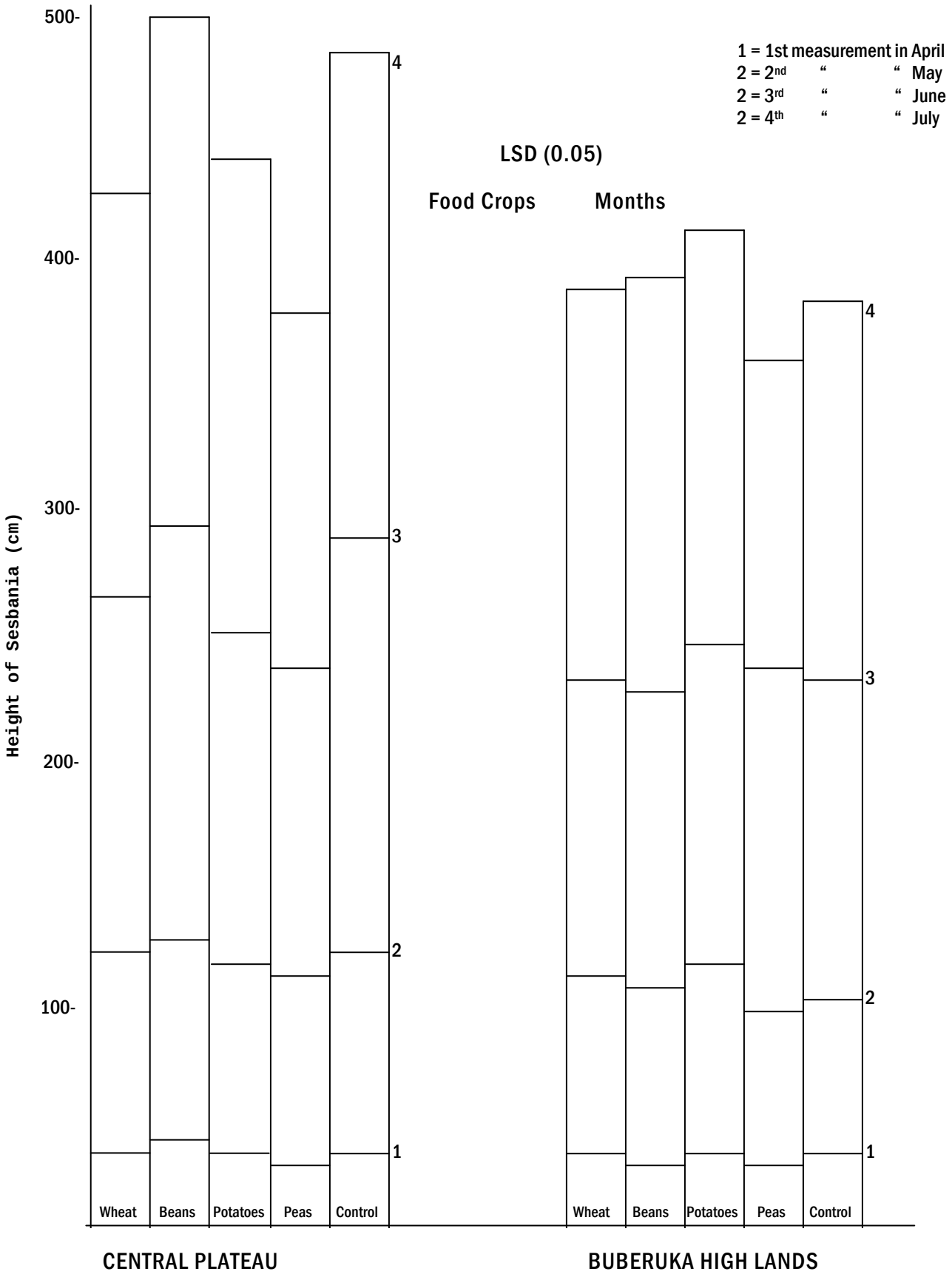

Fig. 1. Growth of Sesbania sesban as affected by food crops in two ecological zones in Rwanda.

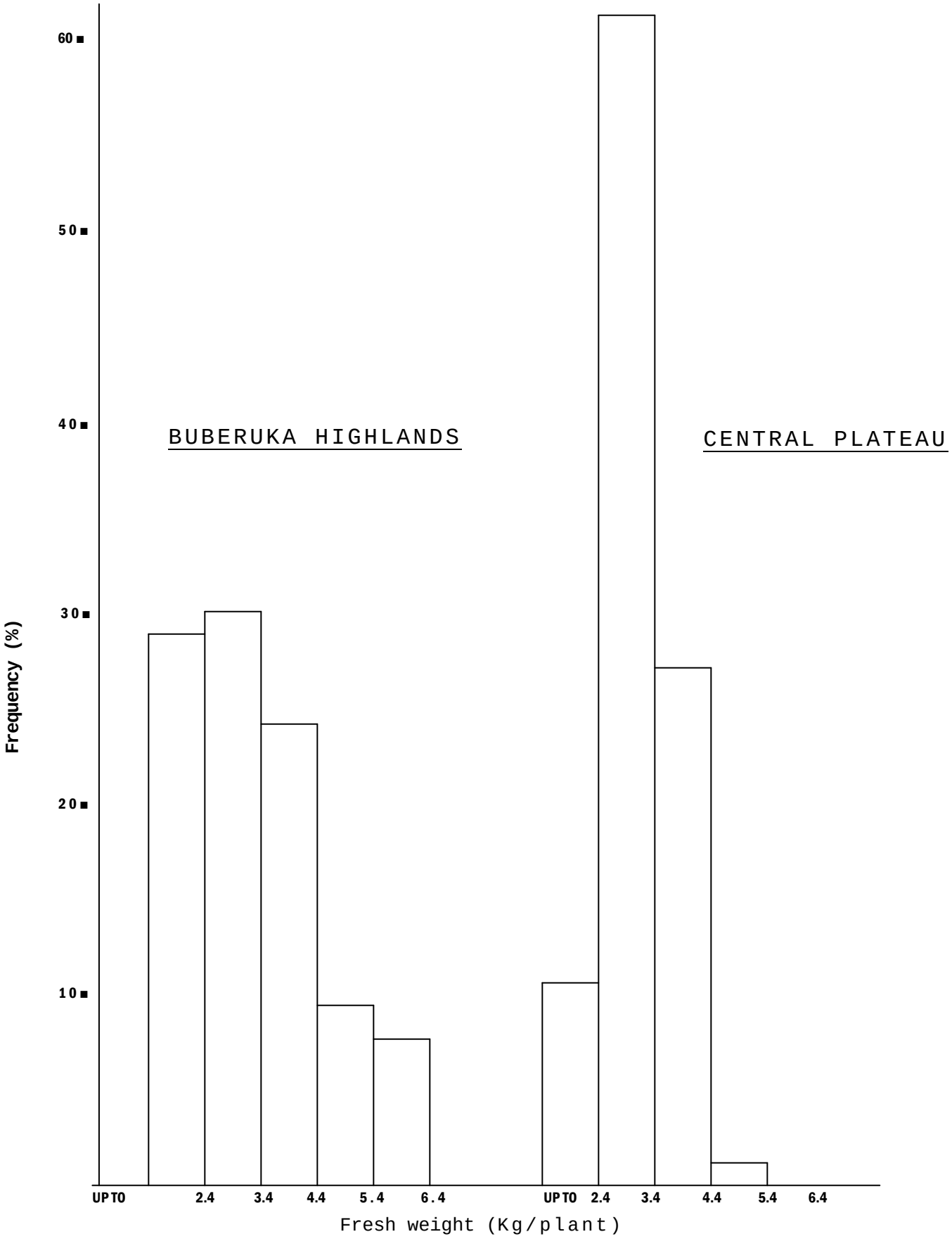

Fig. 2a. Frequency distribution of biomass for Sesbania sesban 1 year after establishment in two ecozones in Rwanda.

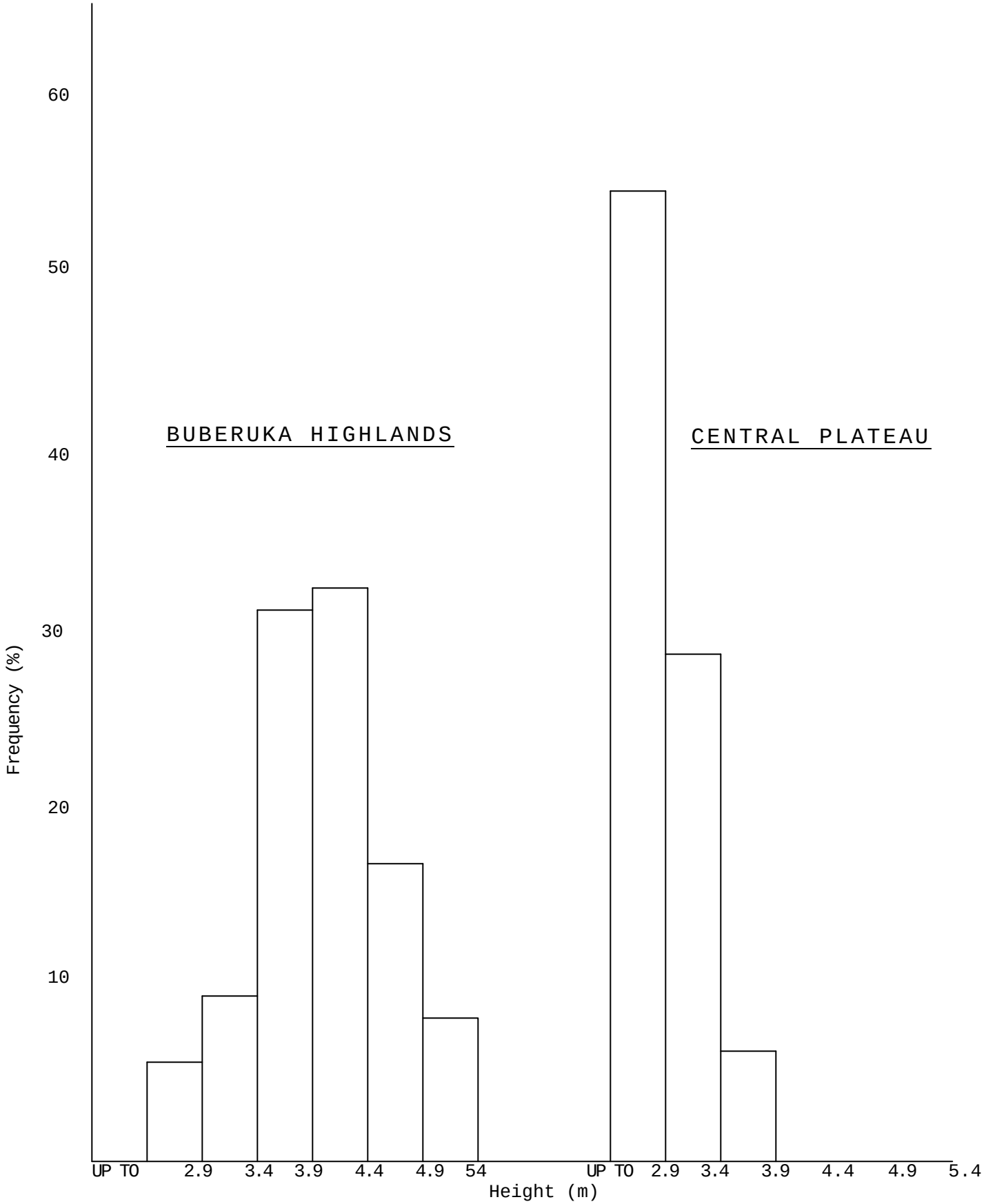

Fig. 2b. Frequency distribution of height of Sesbania 1 year after establishment in two ecozones in Rwanda.

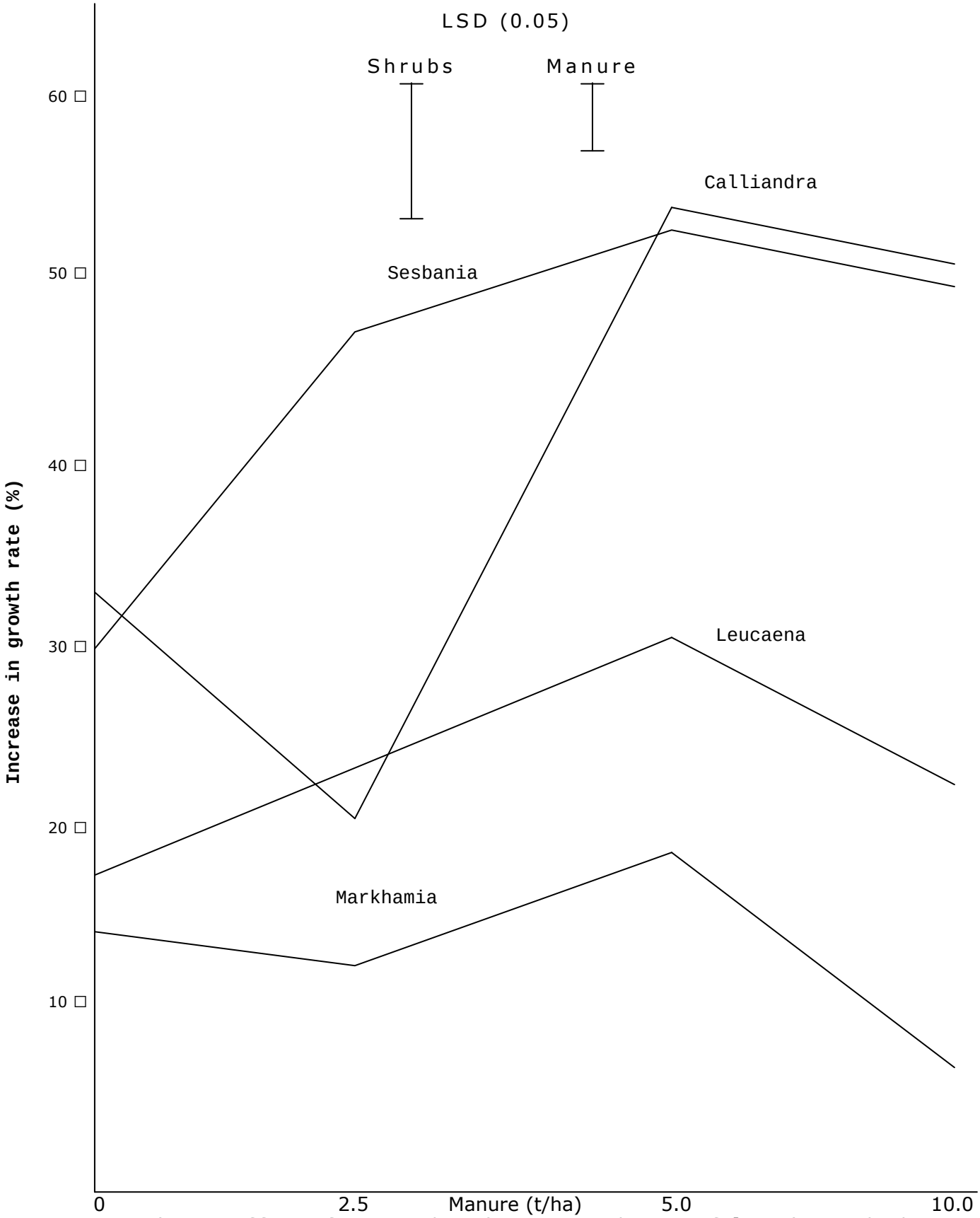

Fig. 3. Effect of manure dressing on growth rate of leguminous shrubs.

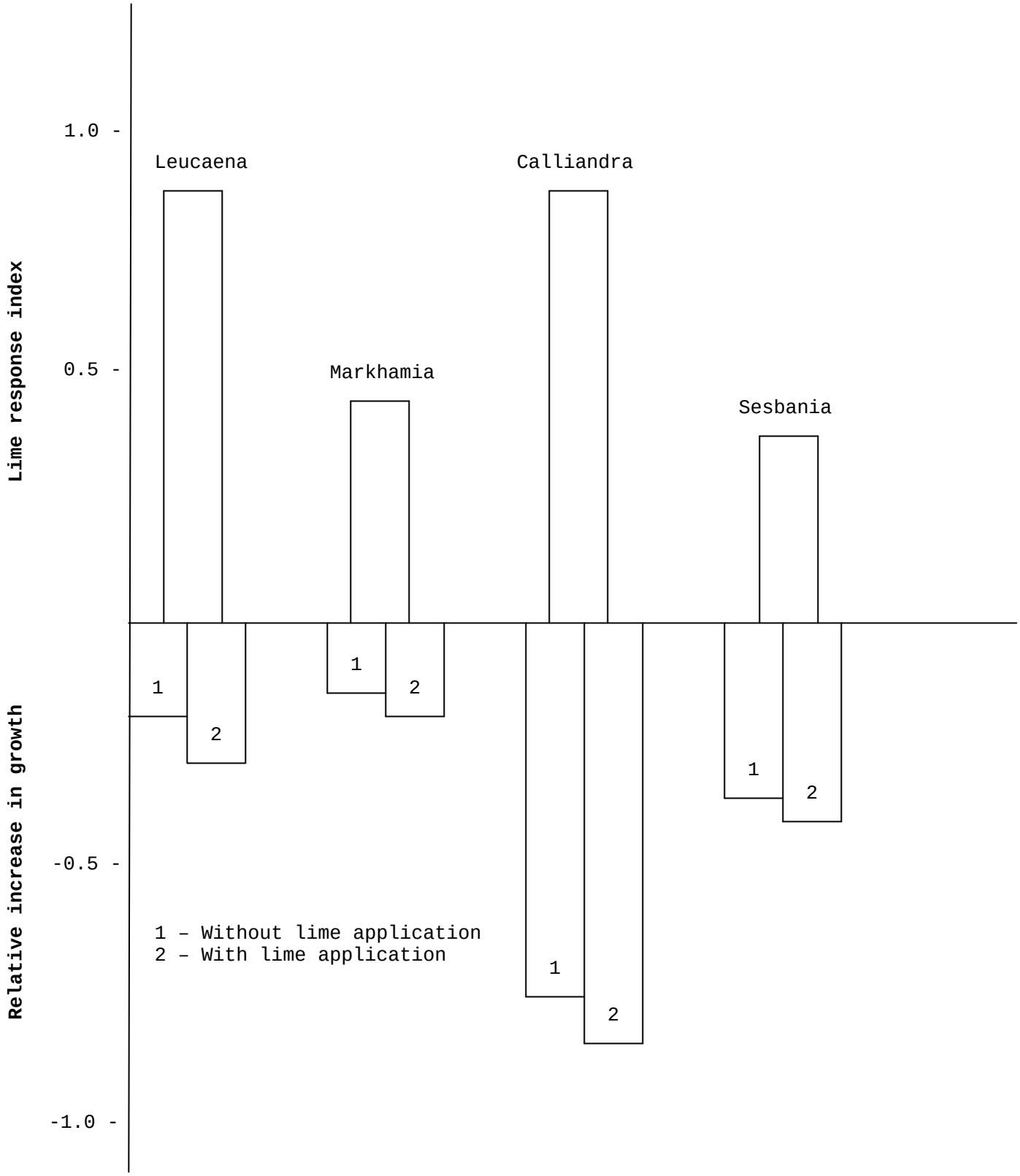

Fig. 4. Growth rates of alley shrubs as affected by the application of lime from a local source in Rwanda.

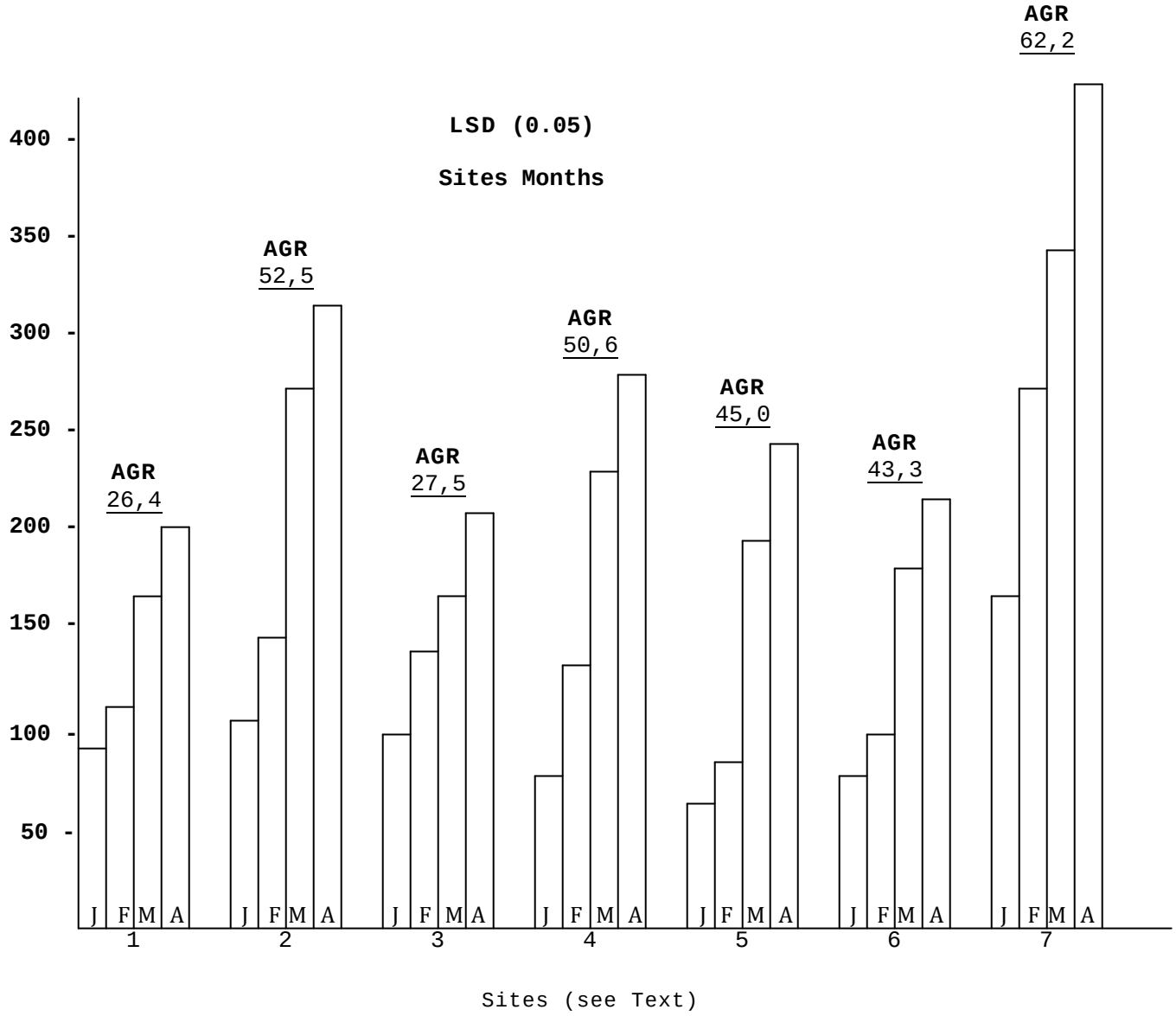

Fig. 5a. Growth of Sesbania in selected micro-ecozones in the highland

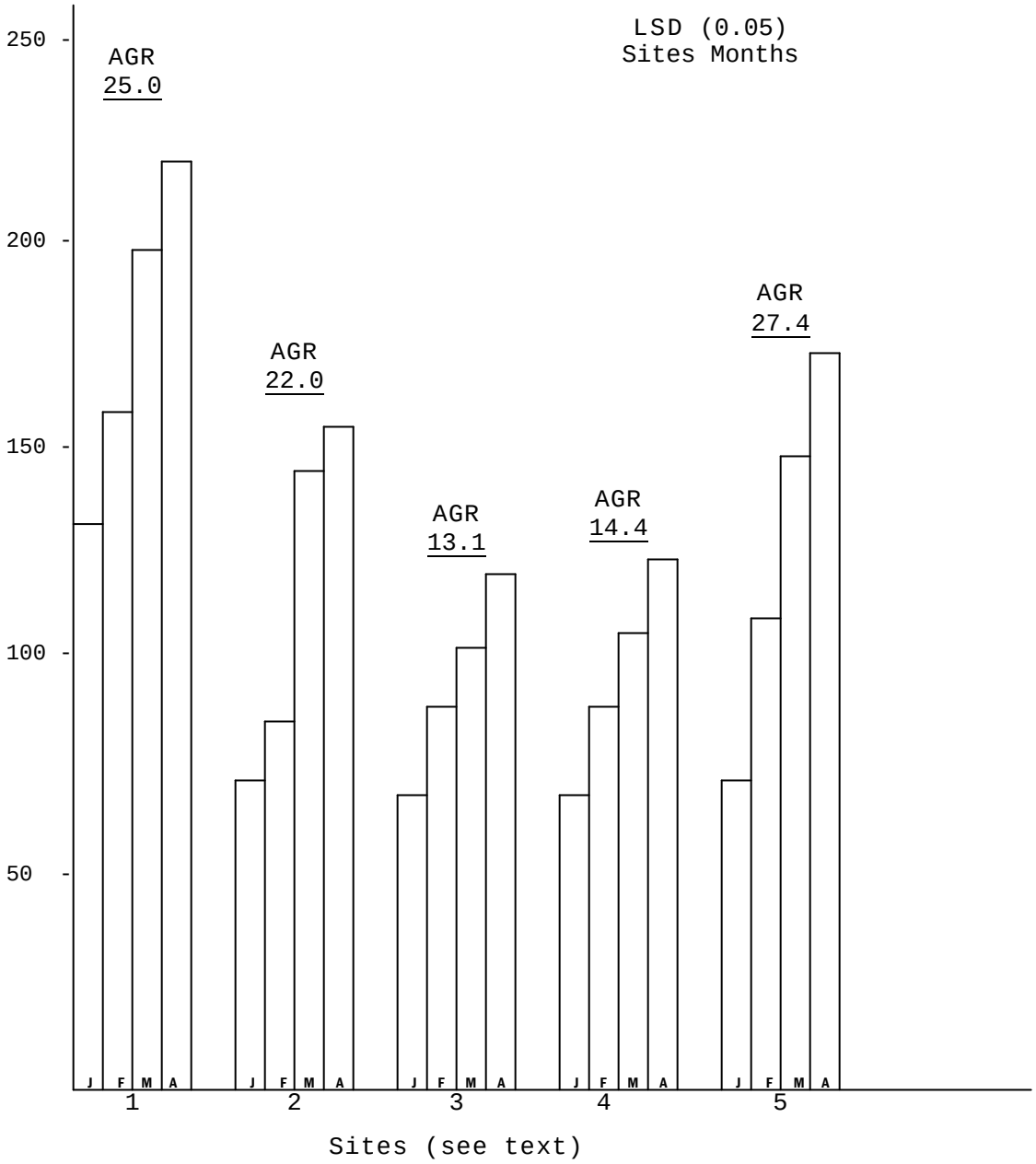

Fig. 5b. Growth of Leucaena leucocephala in selected micro-ecozones in the highland region of Rwanda, 3-6 MAP.

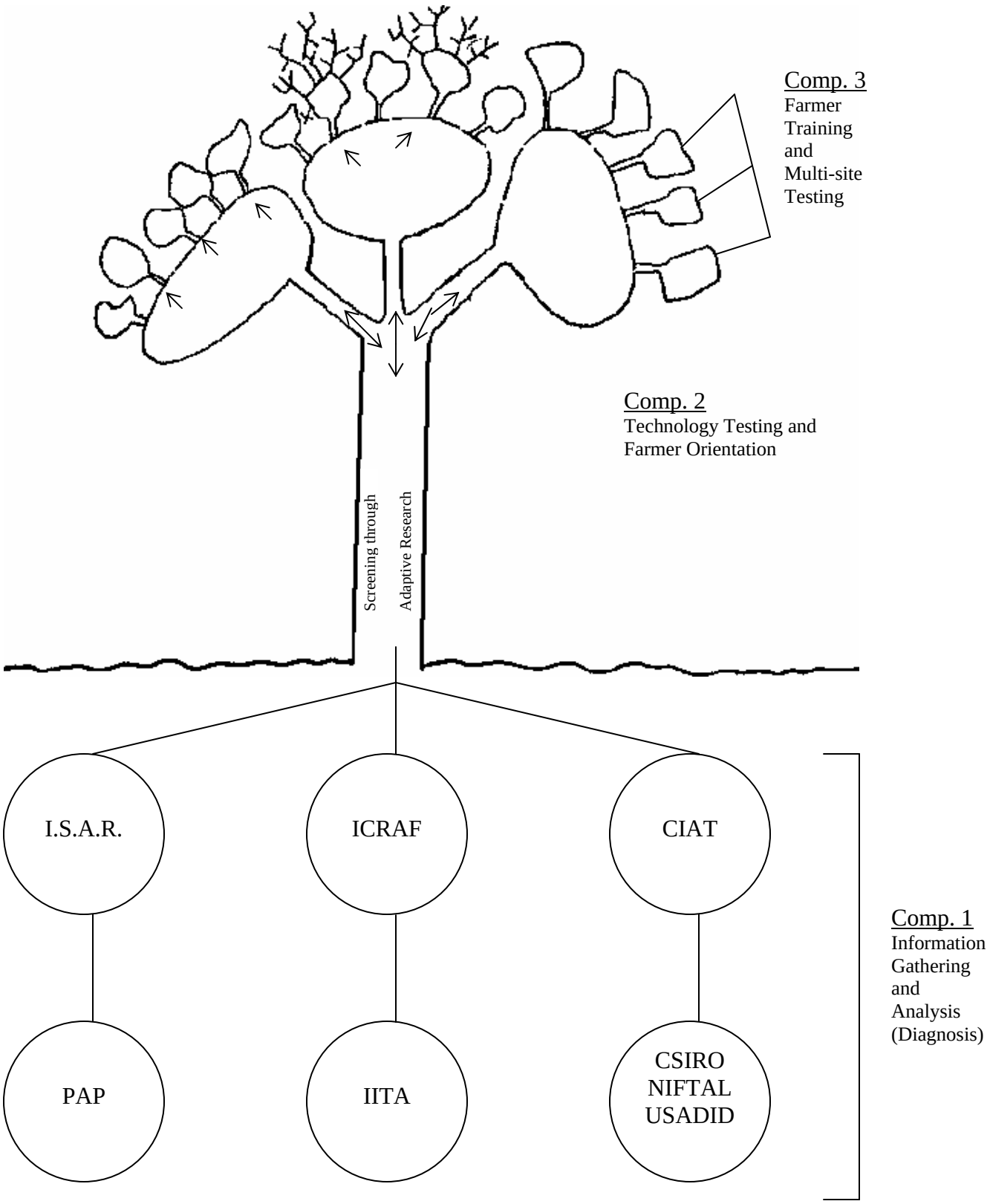

Fig. 6. Agroforestry research methodology.

AN INVESTIGATIVE REPORT OF ON-FARM ALLEY CROPPING TRIALS IN EAST AND CENTRAL NIGERIA: CONSIDERATIONS FOR INTERREGIONAL TECHNOLOGY TRANSFER

Fields Ashley Caveness and Wolfgang Vogel[1]

INTRODUCTION

Population increases in Africa are resulting in a destabilizing of the slash-and-burn agricultural system, which operates effectively when land availability is sufficient to allow long fallow periods for soil restoration. Decreased fallow periods increase the rate of deforestation and decrease land productivity. The need for viable alternatives to traditional food-, crop- and animal-production systems in Africa is being answered by IITA and ILCA with on-farm trials of the alley cropping and alley farming systems.

Eight years of research station and on-farm research in the Oyo State area of Nigeria has resulted in systems that have been adapted and fine-tuned to the needs and environment of the farmers in the area. Spontaneous adoption is now occurring.

Results of on-farm trials in East and Central Nigeria have been complicated by locally specific social and economic conditions and by the distance between the experimenting farmers and researchers. System refinement to fit local conditions and an improved two-way flow of information between farmers and researchers is needed to increase acceptability of the system and its effective use.

A TECHNOLOGICAL NEED

Traditional agriculture in Nigeria has been the slash-and-burn or shifting cultivation methods used throughout the tropics. Until recently, the high ratio of land to people allowed slash-and-burn to be a viable agricultural system. Today, however, population growth has resulted in a relative shortage of cultivable land in many regions of the country. Increased cropping intensity combined with shorter fallow periods is causing deforestation, soil degradation and reduced yields at a time that demands soil conservation and higher yields.

Shifting cultivation, slash-and-burn, swidden agriculture and other names have been used to describe the method of agricultural production used by subsistence farmers in the tropics.

Whatever the name, this method of crop production periodically removes most of the vegetation by cutting and burning, followed by a period of crop growing on the cleared land. The cropping period can last up to 5 years before the land is returned to bush fallow. Historically, the bush fallow period has been 4 to 5 years for every 1 year of crop

[1]2220 Q Street, Lincoln, NE 68503, U.S.A.; International Institute of Tropical Agriculture (ITTA), P.M.B. 5320, Ibadan, Nigeria.

production. Traditionally, people used this system effectively, cultivating plots only after the natural vegetation replenished soil nutrients and re-established the soil structure (Nye and Greenland, 1960).

Alley cropping, a system of producing agroforestry food crops, has been designed to combat degradation of cultivable land brought about by continuous or long-term cropping on farm plots previously rotated to long fallow periods. The alley cropping system allows a farmer to crop for an extended period without returning the land to fallow because the cropping and fallow phases take place concurrently (Kang and Reynolds, 1986).

The alley cropping system plants perennial tree species in hedgerows at 2-m to 4-m intervals in the farm plot. The recommended spacing of the leguminous perennials in the hedgerow is 25 cm to 50 cm. Trial plots are generally 10 m x 20 m.

Alley cropping with hedgerows of Leucaena and Gliricidia has been shown by researchers in Nigeria to be an effective means of preserving arable cropland and prolonging the cropping period of the alley-cropped plot. The system also produces numerous by-products that benefit the farm family. The prunings from the hedgerows provide nitrogen, an essential nutrient for growing quality crops. The deep-rooted hedgerow plants extract nutrients from the subsoil that have been leached out of the crop root zone, into the hedgerow leaves; when the leaves are used as mulch, these nutrients become available to the food crop. The nutrient recycling and atmospheric nitrogen fixation of the hedgerow legumes reduce the need for purchased fertilizer. Increased soil moisture retention, erosion control and increased organic matter and improved cation exchange capacity of the soil are benefits of the alley cropping system.

The leaves of Leucaena and Gliricidia are also an excellent animal feed supplement. Although Leucaena contains mimosine, which is toxic if fed in large amounts, the leaves contain much nitrogen and can be an important source of amino acids for the production of protein by small ruminants.

The stems of the hedgerows that remain after harvesting the leaves for animal feed or for soil mulch have many potential uses. Small stems can be used as fencing material while the large stems, which result after pruning hedgerows following a dry-season fallow period, can be used as yam stakes, firewood and in some cases as construction material for hut building and the like.

Alley cropping is an effective and versatile production system. It is intended to be a long-term system; effective use requires a clear understanding of the benefits. The adopting farmer must be well informed about the management of hedgerows to reap the benefits and to avoid the detrimental effects of improper management. Incorrectly timed pruning of the hedgerows will allow them to shade the food crop; pruning too often or too close to the ground will reduce the biomass produced by the

hedgerows and thus the nutrients available to the companion crop planted between the hedgerows.

IMPLEMENTATION OF TECHNOLOGY

Alley cropping has been proven to be a viable biological system under research station conditions. There are numerous benefits from hedgerow by-products and the primary nutritional contribution to companion crops realized in an optimally managed system. The key words to successful implementation of alley cropping technology are "optimally managed." An optimally managed alley cropping system at the research station includes maize in the alleys using a low-till system of land preparation; a linear-programming model showed the maize/Leucaena combination to be the dominant profit-optimizing system (Verinumbi et al., 1984). Pruning is done by supervised laborers who are trained to prune properly.

A simulation done for an alley cropping system in semiarid conditions in Kenya concluded that alley cropping provided the hedgerows and subsequent pruning tasks were accomplished before the peak labor-demand season (Hoekstra, 1985). Clearly, alley cropping has great potential for success where the on-farm circumstances approach research station conditions.

On-farm Considerations

Adoption of alley cropping or any other technological innovation is certainly a function of agronomic compatibility. However, the goals of a farmer, the social structure of the community and the economic constraints are just as important for successful use of a system.

The successful transposition of technology from the research station to the farmer requires an understanding of local circumstances gained from information gathered by an integrated team of researchers. An interdisciplinary team of agronomists, economists and anthropologists can help to avoid technological failure of a system due to biological, social or economic constraints experienced by a potential adopting farmer (CIMMYT, 1980). While site description is important for designing technology for an environment, equally important is a free flow of information between the farmer and the research team. Feedback of information on successes and problems encountered by the farmer in the use of the technology allows alterations of the system to be made for particular unexpected circumstances. The research team must be able to inspect and(or) hear of problems and advise the farmer as to methods to correct a problem in a timely manner. In Africa this is best accomplished if the team is stationed near the experimenting farmer; long-distance communication is difficult and slow. An office staffed by researchers or by qualified representatives of researchers should be in the area of the implemented technology (Zandstra et al., 1981).

Adoption of a technology by a farmer is a function of access to full information about the technology and its potential and recognition by the farmer of the appropriateness of the technology to his or her circumstances (Feder et al., 1985).

When a farming systems approach is followed, on-farm implementation of technology is likely to be profitable for the farmer because it may be adapted and fine-tuned for the farming circumstances. Both the International Institute of Tropical Agriculture (IITA) and the International Livestock Center for Africa (ILCA) follow this approach in their on-farm alley cropping research. Using the farming systems approach has taught researchers much about the establishment and management problems of farmers trying the alley cropping system (Kang and Reynolds, 1986).

Locally Specific Implementation Success

Alley cropping in Nigeria was designed in Oyo State at the research facilities of IITA and ILCA. Eight years of on-station and on-farm research in Oyo State has shown the biological and economic viability of the system for the agronomic, social and economic environment of the area.

The proximity of research teams to the on-farm trials and the extensive knowledge of Yoruba social systems, land-tenure arrangements and farming systems meet the previously mentioned farming systems criteria for effective systems implementation. The system was designed for the circumstances, and the free flow of information between researchers and farmers has allowed alley cropping techniques to be refined and effectively used. Proper hedgerow establishment, timely pruning and demonstration of the varied uses of the system and its by-products have provided a net economic benefit for many of the farmers who opted to try alley cropping, even though there was apprehension and risk of using an unfamiliar and relatively complicated technology. Spontaneous adoption is now occurring. Researchers and the Ministry of Agriculture in Oyo State cooperate, and alley cropping is promoted by the local ministry.

Alley cropping was designed primarily for maize production, to provide staking material for yams to increase photosynthetic leaf area and thereby tuber size and as a source of animal feed supplement. As such, the system is well suited to Oyo State, which has a ready market for maize, has traditionally practiced yam staking and has a high use of animal products. Further, perennial crops such as cocoa have long been familiar to the area, so the use of perennial hedgerow species poses few land-use problems.

Problems of a Technology Package

Agricultural technologies are commonly introduced as packages that include several components (Feder et al., 1985). Alley cropping is such a package and comprises components of hedgerow seed, Rhizobia innoculant, HYV maize seed, fertilizer and detailed management requirements. The package demands not only knowledge of farmer circumstances and goals, but also adequate infrastructure to distribute the inputs and information. Any gap in the package-support structure will have serious consequences for successful systems implementation.

Research conducted in 1985 for on-farm trials of alley cropping in East and Central Nigeria shows how package-support gaps result in reduced

system effectiveness and farmer enthusiasm and ultimate financial loss for the farmer. This research concludes that the primary problems encountered by experimenting farmers of Benue State in eastern Nigeria were related to poor access to information on management practices while those trying alley cropping in Anambra State in Central Nigeria experienced land-tenure constraints (Caveness, 1985).

EMPIRICAL EVIDENCE

Interviews were conducted and alley-cropped plots were inspected in Zaki-Biam, a remote area of Benue State in eastern Nigeria, and in Mgbakwu, a densely populated area of Anambra State in Central Nigeria (Fig. 1). Evidence of complications was found in both areas. Although certain problems were common to both areas, the primary constraint preventing optimal use of alley cropping in each area was a locally specific phenomenon.

Zaki-Biam

Zaki-Biam is located approximately latitude 7°N in the eastern midbelt of Nigeria in an area classified as southern guinea savannah (Raintree, 1980). The topography is flat with some gently undulating slopes. Crops are rainfed, with rainfall averaging 1,320 mm per year. The topsoil is thin and averages between pH 5.8 and 6.2 (Ngambeki, 1981). It is sandy and easily cultivated with the large, short-handled, traditional hoe. The people of the area speak Tiv.

The area surrounding the Zaki-Biam village is farmland that is one of the main sources of yams in Nigeria. The majority of land, labor and fertilizer is devoted to yam production because yams are the major cash crop. Other crops are produced but in small quantities and for local consumption. The large yam market outside the village serves as a major transfer point for yams that are destined for major urban areas of Nigeria. The market operates year-round, although the heaviest volume is during harvest. There are no financial institutions in the area, and savings are primarily in the form of stored yams held for sale when prices increase late in the season. This strategy is commonly used to provide farmers with cash to pay laborers.

Men control the production and marketing for the large yam industry of the area. Profits are considered to be good by farmers, and the region is known for its production of high-quality, large tubers, even though the practice of staking yams is uncommon.

This yam-producing area is characterized by family farms scattered about the perimeter of the village. Each farming family lives in a family compound. Small compound farm plots are located on the edge of the family compound, and the larger yam plots are beyond the compound farms. The women produce minor crops in the compound plots and care for the few (if any) goats and sheep. Maize is among the minor crops grown. Because the compound farms are near the living quarters, the goats and sheep are kept tied or penned, and women and children gather scarce browse for them.

The introduction of alley cropping was intended to be a symbiotic relationship between increased maize production, provision of needed animal browse and provision of yam-staking material to encourage the adoption of yam staking in the area. Some alley plots were introduced in 1981, but due to the large distance (800 km) between Zaki-Biam and the Oyo State research station of IITA, ongoing instruction of proper management and uses of the hedgerow legumes has not been forthcoming. Further, problems encountered by farmers in their use of the system were not conveyed to researchers, so timely corrections and alterations of the system have been limited. The result is that some plots have been abandoned due to land-preparation difficulties and poor crop yields. Other farmers continue to use the alley plots, but not as was intended.

The abandoned plots were established on land that has been depleted by continuous cropping for years without fallow periods. The misconception by some that alley cropping yielded immediate benefits caused disappointment. Some farmers believed that planting hedgerows would immediately cause the land to "become strong again." Therefore, hedgerow seedlings and maize were planted in depleted soils without fertilizer. Because the alley cropping system takes 2 years and careful management to become established and functional, maize harvests in these plots were naturally very poor.

Some of the hedgerows were dug up when the poor soil of these plots did not miraculously yield well. Other plots were abandoned for a few years, and the hedgerows allowed to grow without pruning. When the farmer decided to try again, the hedgerows were high. High labor and input costs were required to trim the overgrown hedgerows. Cutting tools are scarce and expensive in this area, and even with good machetes, cutting the hedgerows was difficult after years of growth. Some farmers did not attempt to reclaim the plots, which have effectively been lost to crop production.

Farmers who reclaimed their alley plots, and those who used the system more effectively for the past few years, have encountered problems in land preparation. The cultivation system in this area involves creating high ridges on which to plant all crops. The soil is sandy, and the high ridges retain soil moisture. To create the ridges (or high mounds for yams), the short-handled hoe is used to dig and move the soil. The hedgerows planted at 2-m intervals make it difficult for laborers to construct ridges. The hedgerows established lateral roots near the soil surface, making it difficult to create ridges or mounds with hoes.

Alley cropping in this area was introduced to men, largely because the chief aim of researchers was to provide yam-staking material. However, because the package was designed for use with maize as the primary companion crop, the hedgerows were established in the compound plots cultivated by women. With proper communication to both men and women, these alley plots could have provided the men with yam stakes and the women with nutritious mulch for their maize crops plus animal browse for the animals. However, due to the lack of clear and ongoing communication with both men and women as to the nature of the system, women have not benefited from the system.

Again, it is misconceptions that lead to ineffective use of the alley cropping system. Since they believed that the mere presence of hedgerows benefited the maize, the men felt justified in pruning the hedgerows (often too close to the ground) and removing the hedgerow leaves from the maize alley plots of the women to use as mulch for the yams. This meant not only that the maize did not benefit from the system, but also that the potential for providing animal feed was not realized. Further, although the men then had mulch for the yams, the nitrogen content was largely wasted because yams do not need much nitrogen.

Encouraging yam staking in the area has not been effective. The men state as their reason for resisting yam staking that they already produce some of the largest tubers in the nation. They are not convinced that the increased labor costs would significantly increase tuber size -- high-quality, large yams already produced are a lucrative venture. They insist, and possibly rightly so, that the cost of staking yams would not bring an attractive return.

The attempt at increasing animal production through the use of hedgerow prunings has not been successful. Goats and sheep do not always like to eat Leucaena leaves. ILCA has shown that small ruminants need to be "taught" to like the leaves, after which time they will readily eat them. Farmers, both men and women, in this area said that their animals would not eat the leaves of the hedgerows.

The poor performance of the alley cropping system in the Zaki-Biam area is attributable mainly to poor communication from researcher to farmer and farmer to researcher and to an obsolete link between IITA and the regional Ministry of Agriculture. Poor coordination among the researchers has also created problems.

Analysis of Zaki-Biam

Farmers in the Zaki-Biam area recognize that they need innovative technology. It is recognized that an increasing population is creating stress on the land, and there is a desire for methods to maintain and(or) increase the fertility of cropland. Although many of those who have attempted to use alley cropping have had serious complications due to incomplete information, most are anxious to correct the situation and believe that the long-run outcome of the system will be beneficial. As competent farmers and business people, they have made logical decisions in their use of alley cropping, given the incomplete information they have.

There are many reasons for the weak communication links that plague innovative farmers in Zaki-Biam. The alley cropping package was introduced to Zaki-Biam in 1981; since then, institutional competition, personnel turnover, distance and time have left large support gaps.

A rapid turnover of research staff at IITA is partly responsible for problems experienced in Zaki-Biam. The researcher who introduced alley cropping in Zaki-Biam is no longer active in the area. This has disrupted the continuity of the flow of support information. Greater

emphasis on the need to provide continuity to ongoing projects by research institutes would improve the chances for successful adoption of technology. Further, greater effort is needed by both the research institutes and the Ministry of Agriculture to train and motivate nationals to continue the work after the departure of the expatriates (Norman, 1983). There is need for closer ties between IITA and the Ministry of Agriculture in the Zaki-Biam area. When alley cropping was introduced in this area, the Ministry of Agriculture regional headquarters in Makurdi (100 km to the north) showed interest in the project. Since that time new personnel at the ministry have not been informed of the continuous alley cropping program in Zaki-Biam. Unlike the close ties maintained between the ministry in Oyo State and IITA, regional ministry officials in the east are not kept informed and do not offer advice on alley cropping.

Competition among institutions has caused problems for farmers experimenting with alley cropping in Zaki-Biam. IITA started these alley plots with yam staking as the main interest to researchers. The benefits of alley cropping for animal production was not stressed, largely because animal production is the domain of ILCA, although they are not working in the Zaki-Biam area. The goal of yam staking has been unsuccessful due to lack of interest of most local yam farmers. This goal has been further hampered by lack of coordination among researchers from IITA and other institutions. For example, one farmer said that IITA has asked him to stake his yams to test the idea that he would obtain bigger tubers and increased income. Eager to cooperate, he did so, but later researchers from the University of Nsuka told him to remove the stakes because they interfered with another yam experiment that this farmer was conducting in the same plot.

Stronger ties between researchers, government and farmers could help to reduce the inefficiency of information dissemination. Greater collaboration between research institutions and the local ministry extension services could supply the experimenting farmers with the support information they need to successfully use the alley cropping system. Without such efforts, alley cropping in the Zaki-Biam area will continue to be used ineffectively and could ultimately be abandoned due to the misuse of the system and the resulting financial loss and losses of land that have occurred.

Because alley cropping was designed for farming conditions in Oyo State, which is different from conditions in Benue State, the need for a two-way flow of information between farmers and researchers in Benue State is imperative. If a two-way flow of information had been maintained during the last few years, the losses to farmers due to poor management could have been avoided and the difficulties due to lateral roots of the hedgerows could have been contained.

Because land preparation in Oyo State does not commonly involve creating ridges and mounds for crops as occurs in Benue State, the lateral root problem was unexpected. Only through continuous communication can researchers advise farmers on problems in a timely manner. Farmers could have prevented the lateral root problem if researchers had been aware of the problem. These farmers have now been advised to plant

hedgerows at 4-m intervals to eliminate the lateral root problem. However, tardiness of such advice has been costly to many experimenting farmers.

Mgbakwu

While alley cropping problems in the Zaki-Biam area are due mainly to a poor flow of information, the system in Mgbakwu is constrained by land-tenure arrangements. The system was introduced to Mgbakwu farmers by ILCA and focused on the benefits for animal production. Alley farming is a variation of alley cropping that ILCA developed for improving animal production simultaneously with alley cropping. At first alley farming seemed to be appropriate for farmers in Mgbakwu. Maize and animal production are important enterprises, yams are staked, and firewood is scarce. Alley farming, it was thought, could boost production of these products and at the same time preserve cropland that was overworked due to rapid population increases.

Mgbakwu is a village about 8 km from Awka in Anambra State in eastern Nigeria (approximately 6°N in latitude). It is in the midbelt of the nation and is in the savannah transition zone. The topography of the area is undulating, and the higher ground is cropped and scattered with trees. Fallow plots and uncultivated areas are covered with thick grasses. Crops are grown on small compound farms in the village and on gentle slopes that have been cleared outside the village. The crops are rainfed and planted on large ridges or heaps and often have no row arrangement. Soils are lateritic (Atta-Krah, 1984), and rainfall averages 1,800 mm per year. The people of the area speak Ibo.

Farmland surrounding the village is controlled by a number of lineage segments (families) who allocate cropland to village households on a yearly basis; the land reverts back to the lineage segments at the end of the cropping cycle (Francis, 1985). The only land owned by individuals is compound land within the village.

Because cropland is rotated among family members yearly, the establishment of perennial hedgerows for the alley plots requires unanimous consent of the lineage segments and family members. Unable to reach such an agreement, ILCA introduced alley farming to some of the compound farmers on land owned by the farmers within the village. In 1981 these farmers were interested in alley farming as a potential for better crops as well (especially) as a source of year-round animal browse.

Mgbakwu is a village in transition. It is located near three major population centers and is rapidly becoming a suburban town. Village compound farms are giving way to house sites, and interest in the long-term alley farm system has declined. ILCA has an office in the village staffed by two competent Nigerian advisors. Establishing local representation in the village has strengthened support systems and increased the flow of information between farmers and researchers. With the information on farming conditions, ILCA has adapted the alley farming system to meet the changing needs of farmers.

Although the village is growing quickly and the compound farms are becoming house sites, the demand for small-ruminant products is increasing. Farmers are finding it more profitable to sell the land they use for compound farms than to grow food on such land. However, they still keep many animals. To fit this situation, ILCA has introduced a variation of alley farming, which serves the needs of producers of goats and sheep. Rather than growing crops in the alleys and using the leaves of the hedgerows as animal browse, the "intensive feed garden" system supplies only animal feed that is needed most. The feed gardens take little land and are comprised of rows of Leucaena, Gliricidia and Panicum and(or) Pennesitum grasses. This system is considered more appropriate for current village circumstances, and many farmers/animal producers are beginning to use feed gardens. All house sites are large enough to establish small feed gardens.

ILCA has not abandoned alley farming in the area, however. They gained permission to establish a small demonstration plot outside town in an attempt to show the benefits of the system to the lineage segments who control outlying cropland. If and when there is an agreement to adopt alley farming on family land that is rotated yearly, the local ILCA representatives' presence should help to avoid the complications experienced in Zaki-Biam.

CONCLUSION

When properly implemented and managed and adapted to local needs, alley cropping increases the productivity of farm resources. The leguminous trees and their by-products provide valuable inputs to enhance crop and livestock production.

Management of the alley cropping system and the use of the by-products are determined by the resource endowments of an area and the crop production practices.

Successful adoption of innovative agricultural systems depends upon effective dissemination of information to the farming community, as well as upon the implementation of systems that are adapted to local conditions.

Understanding the role of women in the local economy and farming enterprises will help ensure that the system is adapted and implemented to benefit the household and not only male-dominated enterprises. The unintended effects on women maize producers in the Zaki-Biam area could have been avoided if the system had been introduced to both the male yam farmers and female maize farmers, ensuring that both fully understood how the system functioned best.

Reiteration of systems concepts and management practices to adopting farmers is essential. It is imperative that staff trained in agriculture and knowledgeable about the introduced system interact with participating farmers.

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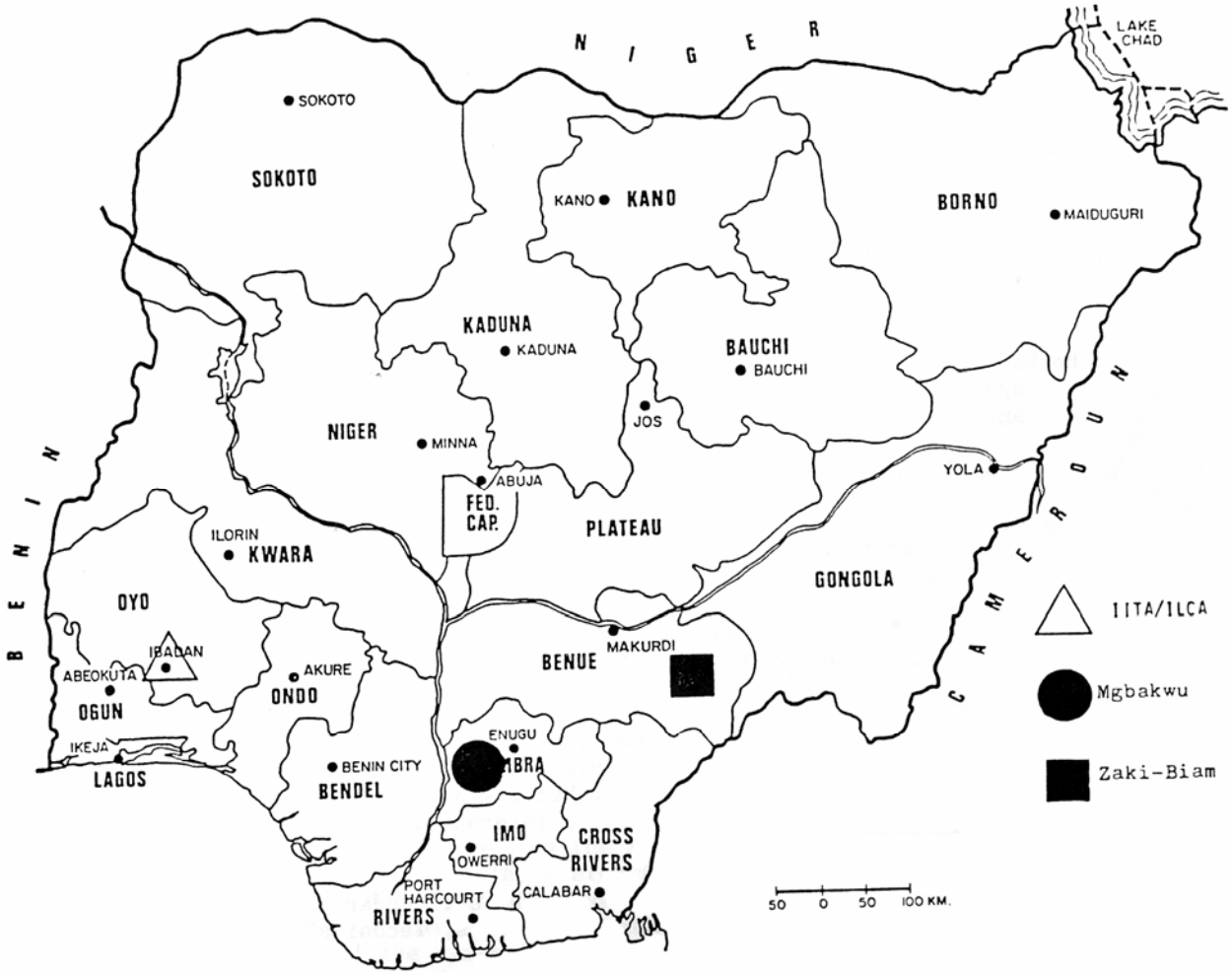

Fig. 1. Map of Nigeria.

Crop Systems

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CROP SYSTEMS

The crop systems section of the 1987 FSR symposium highlights current research trends related to the crop component of farming systems. The majority of the farming systems throughout the world are based on cereal-crop-production patterns, which often include oilseed, tuber and pulse crops in rotation or intercrop associations. As such, the crop component of the total production system contributes significantly to food production and the generation of cash income on farms, ranging in degree of market involvement from totally subsistence to fully commercial production units. Crop by-products are also a principle source of feed for ruminant livestock, especially during the dry seasons when few other feedstuffs are available.

Therefore, an effort was made to select papers for this section of the symposium that discuss the general principles of how crops interact with each other, with other system components and with the larger physical and socioeconomic environment. Attention to social factors and the active participation of farmers in deciding the focus of adaptive research was also stressed. Special emphasis was placed on the conceptualization of the efficient user of farm family resources in crop production through computer-assisted techniques, such as linear and quadratic programming.

On a geographical basis 43% of the papers in the crop systems session of the symposium are based on research from Africa. However, Asia, Latin America and the United States are also represented with approximately the same number of studies presented from each region. The themes of the minor papers fall into the general categories of varietal selection for cropping systems, screening of alternate cropping systems, the relationship of cropping systems to soil nutrient depletion and socioeconomic factors that influence cropping patterns.

The keynote address in the crops section focuses on a study of risk aversion and resource allocation associated with the introduction of new technology for crop combinations in Zaire. This research is an excellent example of how new analytical techniques are being applied in farming system research to derive policy recommendation for domestic and external donor agencies. Other major presentations in the session include an innovative and practical research methodology for varietal selection in maize/bean associations in Haiti, a discussion of the interaction of cultural factors and soil-management techniques in an effort to tailor technical recommendations to ethnic conditions in Indonesia and description of the participation of farm families in determining horticultural research priorities in Virginia.

The consideration of additional social factors, such as the gender of the household head, in the acceptability of new technical innovations is illustrated in a study of maize and soybeans in Malawi. This study suggests the need for diverse strategies for low- and high-resource farmers in regions that are usually described as having a single farming system. Gender issues are particularly relevant for farming systems

researchers in Africa, where women play such a key role in the availability and cost of hired labor.

This allocation of scarce family resources, such as labor and capital, to technological innovations will continue to require careful analysis of risk and returns on investment in farming systems where production is not motivated purely by profit incentives. The interaction of system components demands constant monitoring so that crop varieties and relevant husbandry practices for pest control, soil management and crop associations can be tailored to specific farming systems. The discussion stimulated by papers presented in this section furthers the exchange of information among FSR practitioners who are striving toward the same goals in very diverse physical and ethnic environments.

Richard Harwood, Chair

JOHN BAFFES

John Baffes was born in Kamari, Arkadias, Greece, in 1959 and was raised on his father's farm, in a predominantly agricultural area. He has studied at the University of Athens, Greece, receiving a B.Sc. in economics in 1983 and receiving a M.Sc. in agricultural economics in 1986.

His M.Sc. research was concerned with alternative methods of productivity measurement in U.S. agriculture, which resulted in his thesis entitled "Static and Dynamic Production Models for U.S. Agriculture". His continuing involvement as a research assistant at the University of Georgia concentrated mainly on the analysis of the effects of government policy on agricultural production decisions with specific reference to the Kasai region of Zaire.

Mr. Baffes is presently working towards a doctorate degree at the Department of Agricultural and Resource Economics at the University of Maryland. His current research interests include agricultural development and international trade.

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OPTIMAL CROP COMBINATIONS UNDER RISK: THE CASE OF MAIZE PRODUCTION IN THE KASAI REGION OF ZAIRE

John Baffes, Tshidinda M. Lukusa and Glenn C. W. Ames[1]

INTRODUCTION

Agriculture is characterized by an unstable environment. The biological nature of agricultural production and its exposure to natural elements pose special problems in attempting to forecast yields. Extremes of weather, diseases and insect damage leave farmers with limited defenses against such uncertainty. Major economic events, such as fluctuations in input and output prices, further increase the uncertainties under which farmers operate.

The introduction of advanced farming techniques such as the use of fertilizers, pesticides and mechanization has become standard farming practice in developed countries. However, this is not the only way to improve food and fiber production; other techniques, such as crop combinations or rotations, may be used to reduce farmers' income variability. It has been well documented that farmers in developing countries appear to be more risk-averse than their wealthier counterparts in other countries (Young, 1979; Musser et al., 1984). Given that the introduction of new, capital-intensive technology in developing countries has limited potential due to the farmers' limited financial resources and risk aversion, alternative methods of increasing food production are required. These methods need to consider the farmers' objectives in allocating farm inputs, such as land and labor.

The objectives of this study are 1) to develop a theoretical model of a multiple-crop rotation scheme under risk, and 2) to apply this model to a typical farm in the Kasai-Oriental region of Zaire. This study is organized into five sections. The first section describes agriculture in Zaire. Utility analysis and its relationship to quadratic programming are discussed in the subsequent section. Application of the quadratic-programming approach is described in the third section. The last two sections include the empirical results, policy implications and conclusions.

THE AGRICULTURAL SITUATION IN ZAIRE

Before independence, in 1960, food production in Zaire was sufficient to satisfy domestic consumption requirements with a surplus to export. In subsequent years, production has not kept pace with population growth, which is increasing at a rate of more than 3% each year. Imports of staple foods such as maize, rice, sugarcane and wheat have been necessary. Local maize production supplies about 65% of the average

[1]Graduate research assistant, Department of Agricultural and Resource Economics, University of Maryland; graduate student and professor, respectively, Department of Agricultural Economics, University of Georgia.

annual per capita consumption of 32 kg (Republique du Zaire, 1982). Thus, imports are accounting for an increasing share of staple food consumption.

The Government of Zaire has promoted greater food production through the use of fertilizers, improved seeds, cultivation practices and cropping patterns for the traditional sector of Zairian agriculture. In early 1970, three projects were started to conduct research on maize in the Kasai-Oriental region, where maize is the main staple in the local diet. These projects included the National Institute for Agronomic Study and Research (INERA), the National Maize Program (PNM) and the National Fertilizer Program. Later in 1980, another project, the Maize Project in the Kasai-Oriental (PMKO), was initiated to encourage the extensive use of fertilizers and high-yielding varieties of maize, while existing projects continued research on rotations of maize, leguminous crops, cassava and cotton.

Maize and cassava production in Kasai-Oriental have increased, but there has been little or no change in bean, groundnut and cotton production (Table 1). In addition to the agricultural development projects, there are government regulations that require each farmer to plant a minimum of 0.5 ha of cotton (Mwamufiya, 1977). Failure to cultivate the minimum cotton acreage may result in fines or penalties.

In the Kasai-Oriental region, farmers face considerable uncertainty, and, as a result, yields and prices vary greatly. Given the national food and fiber policies, the allocation of the farmers' scarce resources becomes critically important in meeting household food supply and income objectives.

Agriculture in Kasai-Oriental

Zaire is divided into regions, subregions, zones, collectivities and localities for administrative purposes. The study area, as circumscribed by PMKO since 1980, covers 26,300 km^2, comprising eight administrative zones in the subregions of Tshilenge and Kabinda. The total population of Kasai-Oriental, including the capital city of Mbuji-Mayi, was estimated at 1.6 million in 1984, increasing at an annual rate of 3%.

In the study area of Kasai-Oriental there are two categories of farmers, unsupervised and supervised. The unsupervised farmer does not have access to fertilizer or improved varieties of maize. Furthermore, he is not enrolled in a crop-production program. The supervised farmer uses modern inputs in an effort to maximize his returns and comply with PMKO's recommendation.

Farmers plant in either forest or savannah zones. Most soils in Kasai-Oriental are acidic and contain little organic matter, being a mixture of sand and clay. There are two rainy seasons in the area. The heavy subtropical rains last from late August to late January and are followed by a short 10-to-15-day dry period. A second rainy season begins in late February or early March and lasts until early May, followed by a longer dry season. Seasonal crops of maize follow this rain pattern;

one is planted in August for the heavy rainy season while the other is planted in late January for the light rainy season.

Farm Survey in Kasai-Oriental

A survey of 140 farmers in eight zones in Kasai-Oriental was conducted from July through December 1986. On the average, farmers cultivated 0.6 ha of maize, 0.45 ha of cassava, 0.3 ha of groundnuts, 0.33 ha of beans and 0.3 ha of cotton (Table 2). A prevalent practice was intercropping maize with cassava or beans or interplanting cassava and groundnuts. There was a mixture of monoculture and intercropping in the farming system. Cassava, cotton or other minor crops preceded maize in the rotation cycle. Since PMK0 encouraged farmers to plant crops that would use nutrients in the soil, maize followed maize in the cropping sequence when fertilizer was applied to the first crop (Lukusa, in press).

Farmers in the survey area appeared to be risk-averse, demonstrating a preference for intercropping combinations that reduce the variability in expected returns. Wolgin (1975) argued that risk aversion may help explain why farmers practice intercropping on a large scale. Farmers in the survey area of Kasai-Oriental reported that yield variability increased with the use of improved maize seed and fertilizer beginning in 1978 (Lukusa, in press).

UTILITY ANALYSIS AND QUADRATIC PROGRAMMING

In this study, risk is assumed to arise from variation in productivity, yields and prices. These three components contribute to variation in farm income, which in turn constitutes the variable selected in this study. As has been already indicated, farmers in developing countries are generally risk-averse. They practice diversified farming to take advantage of the complementarily in cropping activities and to minimize variation in aggregate farm income.

Traditional analysis suggests the use of strategies such as diversification and insurance to minimize risk, without considering all the farmer's objectives.

QP models, based on Markovitz' initial definition, "express maximization of expected utility as a function of expected value and variance for an economic parameter such as net income, wealth or consumption subject to linear constraints" (Musser et al., 1984). This technique generates an efficient set of solutions from which farmers can select their preferred plans.

Following Freund (1956), the decision-maker's expected utility function in quadratic form is given by:

$$EU = E + (\alpha/2)V \qquad (1)$$

where E is expected income, V is variance, and α is a non-negative risk-aversion parameter. More specifically, Freund's model is as follows:

$$\text{Max } EU(X) = R\tau X - (\alpha/2)X\tau QX,$$
$$\text{subject to } AX < B \qquad (2)$$

where X is an (nx1) vector of activities, R is the (nx1) vector of expected returns associated with each activity, Q is the (nxn) variance-covariance matrix of activities, A and B are the linear-constraint matrix and vector-of-resource restrictions, respectively, while τ denotes transposition.

Application of Freund's model and QP formulations generally require several assumptions. First, it must be assumed that the individual's goal is to maximize expected utility. A subsequent assumption is that the utility function is quadratic and that expected net returns from activities are normally distributed whereas variance-covariance parameters are nonstochastic or subjective. Finally, QP assumes that the iso-utility curves are convex, which implies that the α risk-averse farmer holds preference among alternative plans solely on the basis of his expected income (E) and the associated income variance (V).

DATA AND OPTIMIZATION PROCEDURE

To build QP models for the purpose of a return-risk analysis, it is necessary to define a utility function with expected mean value and variance of returns (E-V approach). Such E-V analysis supposes that expected returns and the variances and covariances among all enterprises are known.

More specifically, the objective is to find the farm plan that maximizes the farmer's utility. For E-V analysis, this goal is achieved by minimizing the variance of expected income desired by the farmer. The expected returns, variances and covariances are substituted into the quadratic utility function, and the resulting expression is maximized.

As a first step in the analysis, the alternatives from which the farmer can choose must be specified. In light of Mwamufiya's observation and Lukusa's survey in the study area, it was assumed that farmers plant more than one plot of maize in rotation and intercrop with cassava, beans, groundnuts and cotton. These were the alternatives considered in the present study.

Both traditional and high-yielding varieties of maize are planted in the subregions. Most farmers consider maize to be a high-yielding but unstable crop. However, its low cash outlay gives an additional incentive for farmers to plant it as a main food crop. Another food crop is cassava, which has characteristics that reduce the risks of complete crop failure and famine. Cassava matures within 18 months; roots that are not needed are stored underground in the field with no risk of deterioration. In addition, cassava adapts well in poor soil.

Cotton is also included in the cropping system since its cultivation is mandated by the political authorities. This crop is characterized by stable yields, but because of high cash outlays and declining profitability, producers are less motivated to cultivate cotton. Finally,

beans and groundnuts are included in the analysis because of their importance in the local diet.

For each crop planted, data were collected for crop prices received by farmers, quantities produced and prices of inputs. These data were used to calculate net returns (appendix A) as follows:

$$R_i = P_i Y_i - W_j U_j \tag{3}$$

R_j is the net revenue from crop i; P_i and Y_i are market price and yield, respectively; W_j and U_j are prices and quantities of input j. Seasonal residuals are obtained by using the detrending technique:

$$R_i = \alpha + \beta T \tag{4}$$

where R_i represents net returns of crop i, and T represents time trend. These residuals are used to calculate the correlation among net returns of different crop activities. Covariance relationships, particularly when negative, are useful in identifying possible diversification among farm enterprises to hedge against uncertainty.

Net returns along with the variance-covariance matrix, constructed from the residuals, constitute the objective function. The second step is to define the constraints that determine the feasible region of the optimization procedure. Labor availability and minimum food requirements for the typical family are the two major constraints that affect the optimal input and product mix. It was assumed that two adults will devote 600 days annually to crop production. Since one 6-month season was used as the base period, the labor constraint was 300 person-days. Coefficients for this constraint were derived from the labor requirements for each crop activity (listed in appendix B). The second major constraint is the minimum food requirements of farm households. A typical family in the study area required 994 kg of maize, 173 kg of cassava and 80 kg of beans and groundnuts for consumption in each season (Republique du Zaire, 1982). The typical farm family consisted of two adults and three children.

Two typical farms were identified. The first farm was supervised by the PMKO, which required farmers to use a minimum amount of fertilizer in combination with a high-yielding variety (HYV) of maize. In addition, these farmers have a minimum cotton allotment of 0.3 ha. These requirements are incorporated into the analysis as constraints. For the second farm, the local variety of maize without fertilizer is planted because these farmers have not been enrolled in the PMKO program and thus did not have access to fertilizer and HYV maize.

Having defined the objective function and constraints for the two alternative farms, the next step was to use the QP algorithm to obtain the optimal solutions for both supervised and unsupervised farms. Net returns for each of the activities indicate that the first season of each year has higher returns than the second season. This suggests that additional information may be useful in analyzing ways to reduce the variability of returns.

To investigate whether the sample consisting of net returns of the first season in each year (henceforth denoted as the high-yield season) and the sample consisting of net returns of the second season in each year (henceforth denoted as the low-yield season) have been generated from the same population, the Chow test was applied (Kennedy, 1985). Test statistics (reported in appendix C) are calculated by regressing net returns on time trend, and the result is rejection of the hypothesis that the two samples come from the same population as the original sample. More specifically, F-statistics range from 23.36 to 170.57 and 92.53 to 437.20 for the high- and low-yield seasons, respectively, while the corresponding F-value is 10.56 ($\alpha = 0.10$).

Two different QP specifications were formulated, one for the high-yield season and one for the low-yield season for both supervised and unsupervised farms. The new QP specification, which takes into account seasonal variabilities in net returns, is as follows:

$$\text{Max } EU_i(X) = R_iX - (\alpha/2)X\tau Q_iX$$
$$\text{subject to } A_iX < B_i \qquad (5)$$

where $EU_i(X)$ is the total utility that the individual derives at the ith season, R_i is the vector of expected net returns of the ith period, Q_i is the variance-covariance matrix, and A_i and B_i are the matrix of constraints and its corresponding upper (or lower) limit of the period i, respectively. A_i and B_i depend on the optimal solution obtained at the (i-1) period.

EMPIRICAL RESULTS

The optimization problem was solved by using the RAND QP/360 algorithm available on the IBM computer. Since the number of variables and constraints was small, there was no need to employ any of the linearized approximations designed for solving large problems. Since the objective of the study was to determine the optimal-input farm allocation, given that farmers are risk-averse, no attempt was made to identify optimal QP solutions based on alternative risk levels. Several criteria for selecting such solutions have been proposed. Safety First (Roy, 1952) and Stochastic Dominance (Hadar and Russel, 1969; Hanoch and Levy, 1969; Hardaker and Tanago, 1974) have been two widely used criteria. Barry and Robinson (1975) also proposed a practical way of selecting an optimal plan under risk.

To capture a complete picture of the problem, three alternative scenarios were considered (Table 3). Combined with their linear-programming (LP) counterparts, a total of six alternatives were analyzed. The first scenario assumes that the government gives the farmer enough fertilizer and HYV maize seed to plant 0.30 ha. In addition, the average area devoted to cotton by farmers in the survey area was 0.3 ha, less than the official allotment of 0.5 ha. This scenario is consistent with the governmental policy for supervised farms. The second scenario is similar to the first, with one difference. Although the farmer has access to fertilizer and HYV maize, he has the option of not using them. In addition, there is no cotton

allotment. Finally, the third scenario assumes that the farmers do not have access to fertilizer and improved maize seed. This is typical of the traditional unsupervised farms.

The solution under the first QP scenario indicates that the farmer will allocate 0.72 ha to maize (0.42 ha to HYV maize without fertilizer and 0.3 ha to HYV maize with fertilizer), 0.56 ha to cassava, 0.14 ha to beans and 0.31 ha to groundnuts. Finally, 0.3 ha will be planted to cotton, which is the minimum requirement set by the government. No use of the local variety of maize is suggested by this solution. This is to be expected since the local variety is seldom responsive to fertilizer use. In comparing QP with the LP alternative, which implicitly assumes that farmers are risk neutral, an increase in land planted to cassava of up to 1.37 ha is suggested, while no land is allocated to HYV maize without fertilizer. The area devoted to groundnuts is also reduced. QP more closely approximates the land use of farmers in the study area.

The above land allocation holds for the first (high-yield) season. The corresponding results for the second (low-yield) season are also reported in Table 3 (under the heading, Season B). Both QP and LP alternatives are considered. The obvious differences in the results obtained for the two seasons validate the hypothesis that two QP models are needed since the outcomes are different. For instance, farmers' risk and the mean returns of the second season suggest that the farmer use only HYV maize with fertilizer, while in the first season he plants HYV maize without and with fertilizer.

Some differences are observed when comparing the first with the second scenario. In the second scenario, farmers do not allocate any land to cotton production, while the land allocated to cassava is increased. The difference between these two scenarios results from government restrictions on the use of inputs. This may explain why governmental programs do not always succeed. The LP solution gave different results, which diverge from the actual land allocation. Some differences may also be observed when comparing the first with the second season for the second scenario. These differences support the hypothesis of analyzing the two seasons separately.

The third scenario relates to the unsupervised farmers. Under this alternative, farmers have access to neither HYV maize nor fertilizer. In addition, no cotton is assumed to be planted by these farmers. The QP solution gave 1.08 ha for maize (local without fertilizer), which is much higher than the average actual allocation, while for cassava the QP solution was 0.08 ha, much lower than the area planted. The LP solution again provided different outcomes with respect to the various alternatives. This supports the conclusions derived from the other scenarios about the role of risk in allocating inputs and determining product mix.

CONCLUDING REMARKS

Perhaps the most important conclusion of this analysis is that farmers take risk into consideration when making allocation decisions. This is verified by the linear-programming solutions that were not only

different from the quadratic-programming solutions but also diverged from observed land use in the study area. Therefore, risk cannot be ignored in making recommendations for changes in farming systems.

A second important conclusion relates to the effects of government intervention on farming activities. The solution, based on the assumption that farmers have access to HYV maize and fertilizer but are not required to use them, was different from the solution derived when governmental restrictions were imposed. The different outcomes indicate that government programs may not always be in the best interest of farmers. An excellent example is the case of the cotton allotment for farmers in the study area. Although according to the PMKO program the supervised farmers ought to allocate 0.5 ha to cotton, the survey revealed that on the average only 0.25 ha to 0.3 ha were actually allocated. Furthermore, solutions to the second scenario, with no governmental restrictions, indicated that no area would be planted to cotton.

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Table 1. Crop production in Kasai-Oriental, 1978 to 1984.

Year	Maize	Cassava	Beans	Groundnuts	Cotton
	----------1,000 mt----------				
1978	51	1,257	17	30	4
1979	58	1,277	18	30	6
1980	75	1,452	18	31	7
1981	84	1,508	18	31	4
1982	100	1,373	11	30	4
1983	98	1,412	12	31	6
1984	127	1,955	18.3	31.7	5

Source: Zaire, 1982.

Table 2. Land allocated to crops in the study area of two subregions of Tshilange and Kabinda, Kasai-Oriental.

Zone	Inter-viewed	Maize	Cassava	Ground-nuts	Beans	Cotton	Total
		----------ha planted----------					
1	25	.85	.7	.4	.5	.4	2.85
2	20	.7	.65	.35	.3	.25	2.25
3	20	.65	.3	.4	.4	.2	1.95
4	14	.7	.55	.4	.3	.35	2.3
5	8	.35	.25	.2	.2	--	1.0
6	15	.5	.35	.25	.25	--	1.35
7	20	.5	.4	.28	.35	--	1.53
8	18	.6	.4	.25	.3	--	1.55

Source: Lukusa, in press.

Table 3. Optimal land use under three alternative scenarios (measured in hectares).

Crop activity		Season A						Season B					
		I[1]		II		III		I		II		III	
		QP	LP	QP	LP	QP	LP	QP	LP	QP	LP	QP	LP
P1[2]	.00	.00	.00	.01	1.08	1.08	.00	.00	.00	.00	1.08	1.08	
P2	.00	.00	.00	.00	--	--	.00	.00	.00	.00	--	--	
P3	.42	.00	.62	.00	--	--	.00	.00	.00	.00	--	--	
P4	.30	.54	.19	.54	--	--	.63	.86	.63	.86	--	--	
P5	.56	1.37	.79	1.82	.08	.65	.56	1.37	.79	1.82	.08	.65	
P6	.14	.14	.14	.14	.14	.14	.17	.17	.17	.17	.14	.14	
P7	.31	.11	.34	.11	.39	.11	.39	.12	.17	.17	.13	.13	
P8	.30	.30	.00	.00	--	--	.30	.30	.00	.00	--	--	
Total	2.03	2.46	2.08	2.61	1.69	1.98	2.05	2.82	1.76	3.02	1.43	2.0	

[1] I = Supervised farm with governmental restrictions.
II = Supervised farm with no governmental restrictions.
III = Unsupervised farm.

[2] P1 = local maize without fertilizer, P2 = local maize with fertilizer, P3 = HYV maize without fertilizer, P4 = HYV maize with fertilizer, P5 = cassava, P6 = beans, P7 = groundnuts, P8 = cotton.

Appendix A. Seasonal net returns for all crop activities

Season		P1[1]	P2	P3	P4	P5	P6	P7	P8
1979	A[2]	32.60	32.60	32.60	32.60	48.00	28.20	37.80	33.30
	B	29.20	29.20	29.20	29.20	27.00	19.50	36.00	24.00
1980	A	104.65	104.65	104.65	104.65	119.70	72.00	88.00	31.64
	B	45.60	45.60	45.60	45.60	43.20	36.80	35.00	24.50
1981	A	280.50	336.80	325.50	666.80	395.55	150.80	186.00	24.64
	B	124.60	115.70	130.20	328.50	218.16	83.20	148.50	12.90
1982	A	361.80	531.80	419.40	866.60	298.35	195.00	150.80	33.60
	B	211.20	251.10	232.80	404.70	166.95	109.20	105.00	18.30
1983	A	215.05	375.25	247.25	525.85	309.87	189.00	345.60	55.00
	B	132.80	192.00	156.80	316.80	201.60	81.70	117.60	37.35
1984	A	173.70	160.80	231.30	304.80	282.00	286.00	380.80	52.00
	B	85.80	89.60	91.30	123.70	178.20	136.30	265.50	24.78
1985	A	196.35	256.95	232.05	361.05	280.50	254.80	400.20	42.70
	B	95.70	86.70	99.00	146.10	189.00	147.20	164.66	31.20
1986	A	424.24	233.12	239.25	373.95	240.00	171.60	295.00	70.50

[1] P1 = local maize without fertilizer
P2 = local maize without fertilizer
P3 = HYV maize without fertilizer
P4 = HYV maize with fertilizer
P5 = cassava
P6 = beans
P7 = groundnuts
P8 = cotton

[2] A = high-yield season
B = low-yield season

Appendix B. Coefficients used for all QP alternatives.

Activity[1]	ESNRHS (za/ha)[2]	ESNRLS (za/ha)	ESYHS (kg/ha)	ESYLS (kg/ha)	LR (pd/ha)	MFR[3] (kg/sn)
P1	244.94	130.02	916.6	837.1	186	994
P2	315.87	14.07	1,244.5	1,032.9	196	--
P3	82.45	142.02	1,052.1	891.4	186	--
P4	521.01	263.96	1,827.4	1,574.3	196	--
P5	300.54	190.78	8,713.8	8,820.0	81	173
P6	207.86	11.52	562.5	480.0	193	80
P7	293.07	180.24	730.0	655.7	166	80
P8	46.41	24.91	408.6	336.4	122	--

[1] P1 = local maize without fertilizer
P2 = local maize with fertilizer
P3 = HYV maize without fertilizer
P4 = HYV maize with fertilizer
P5 = cassava
P6 = beans
P7 = groundnuts
P8 = cotton.

[2] ESNRHS = Expected seasonal net returns for high-yield season.
ESNRLS = Expected seasonal net returns for low-yield season.
ESYHS = Expected seasonal yields for high-yield season.
ESYLS = Expected seasonal yields for low-yield season.
LR = Labor requirements.
MFR = Minimum food requirements.

[3] za = Zaire (Zairian currency)
pd = person-days, sn = season.

Appendix C. Chow-test results.

Model[1]	SSE1[2]	SSE2	SSE3
P1	15,665 (40.66)[3]	6,404 (113.07)	58,127
P2	50,343 (28.88)	15,954 (115.25)	147,992
P3	14,319 (60.1)	8,864 (108.28)	77,427
P4	86,717 (35.23)	18,623 (204.32)	290,415
P5	3,225 (170.57)	1,374 (392.53)	39,898
P6	11,333 (35.25)	1,178 (437.2)	37,965
P7	28,432 (23.36)	9,556 (92.53)	72,717
P8	418 (54.26)	196 (123.86)	1,930

[1] P1 = local maize without fertilizer
P2 = local maize with fertilizer
P3 = HYV maize without fertilizer
P4 = HYV maize with fertilizer,
P5 = cassava
P6 = beans
P7 = groundnuts
P8 = cotton.

[2] SSE1 = sum of squared residuals using high-yield season’s net returns.
SSE2 = sum of squared residuals using low-yield season’s net returns.
SSE3 = sum of squared errors for restricted model.

[3] Calculated F-statistics in parenthesis.

EXPERT SYSTEMS:
A POSSIBLE LINK FROM FIELD WORK TO POLICY IN FSR

Carol J. Pierce Colfer, Russell Yost,
Fahmuddin Agus and Stacy Evensen[1]

INTRODUCTION

Farming systems research (FSR) has taken many forms over the past few years and engendered many disputes. However, its utility in agricultural development is established among a large number of practitioners. Many people have spent years working in remote areas on farming systems projects with farmers and scientists in other disciplines.

During 3 years of intensive field work and numerous studies in rural Sumatra, a huge body of scientific data was collected by the authors. Although much of the information was relevant for project decision-making and priority setting, it had wider applicability.

The authors wanted their research results to serve some practical, people-oriented goals -- on as wide a scale as possible. Publication of scientific papers in English is an ineffective method of disseminating the findings to Indonesian hosts and collaborators, as well as to co-team members from different disciplines. Motivated and interested scientists from one discipline have difficulty understanding papers that meet the technical standards of another discipline (even in their native language).

This quandary prompted experimentation with "expert systems" (discussed later). The information collected about people is integrated into an expert system that provides recommendations about agricultural research and development in Indonesia based on a holistic, people-oriented perspective. This is an experiment, and the outcome is uncertain.

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[1]Carol J. Pierce Colfer (anthropologist, on leave) and Russell Yost (agronomist/soil scientist) are associate researchers at the University of Hawaii's Department of Agronomy and Soil. Fahmuddin Agus is on leave from the Centre for Soil Research in Bogor, Indonesia, working on a Ph.D. in soil science at North Carolina State University. Stacy Evensen (nutritionist) is on leave from the Tropsoils project. Colfer was first farming systems researcher and then team leader on the Tropsoils-Indonesia Project in Sitiung, West Sumatra. Yost is the leader on Tropsoils' expert systems subproject. Fahmuddin Agus was a team member active in tillage research and frequent acting site coordinator in Sitiung. Evensen was a leader in Tropsoils' home garden work in Sitiung.

There were several considerations in the difficult task of developing farmers, the expert system:

1. There is a general perception that access to sociocultural factors is costly and of uncertain value. A good expert system could provide some of this input at a low cost (both in money and time). An expert system should be able to substitute for a consultant, to some degree.

2. Even in projects where information about people is available, it is sometimes ignored. Agricultural practitioners may be unwilling or unable to read pages and pages of another discipline's jargon (or social scientists may be unwilling or unable to describe their findings succinctly and clearly). The expert system software

   - encourages the creators of the system to streamline concepts and definitions and identify causal links;

   - processes most jargon internally so users are oblivious to most of it (although they will encounter some).

   Users -- whether policy-makers or other farming-systems team members -— can get a simple, clearly defined recommendation in English (or another language) in a short amount of time.

3. There is great diversity among rural areas of different parts of the world. What works in one place or with one group of people does not necessarily work, in another situation. The capacity of the expert system to store vast quantities of location-specific information allows us to incorporate diversity more effectively into decision-making at various levels -- by making location-specific information available.

4. Anthropologists collect vast quantities of information that can be put into the causal statements required by a rule-based expert system. The process of translating ethnographic information into a series of "if x, then y" rules may elucidate some general principles that escape us when we use our usual approach. This process likewise forces us to identify specific factors that lead to practical agricultural recommendations -- something most anthropologists (including Colfer) resist.

WHAT IS AN EXPERT SYSTEM?

Expert systems are computer programs designed to use human knowledge to solve concisely defined problems. Knowledge and experience from human "experts" are incorporated in the program using symbolic logic and heuristics -- rules of thumb. Thus, in a quick, consistent and inexpensive manner, the knowledge gathered through years of research can be accessed and applied to specific problems. This artificial expertise is easy to transfer and document and can be made readily available to people in related fields -- other researchers, policy-makers, educators and the like.

There are several kinds of expert-system software (or shells) currently in use, and more are being developed. We have used EXSYS, version v.3.2 (EXSYS, Inc., Albuquerque, NM, U.S.A.), for the system discussed in this paper: FARMSYS.

To use the completed FARMSYS knowledge base, a user will need an IBM-compatible microcomputer with at least 256K of memory. To create an expert system, using "editxs," a specially developed rule editor, one needs an IBM-compatible microcomputer with at least 640K of memory. Expert systems as discussed in this paper will be based on the EXSYS software.

The purpose of an expert system is to provide a user with access to knowledge that would otherwise be available only from an expert. Ideally, a user could take an EXSYS program diskette and a diskette with an expert system like FARMSYS on it and receive advice (or a recommendation) on a topic included in the expert system, e.g., a medical diagnosis, a liming requirement (ACID4) or the best kind of fish to stock in a fish pond (FISH). FARMSYS provides recommendations related to agricultural research and development.

EXSYS operates by chaining backwards from each "choice" (or recommendation) through a series of rules (which are constructed in an "if-then" format). This process leads users through a series of questions about their specific situations. The answers to these questions determine the appropriate "choices" (or recommendations) and the probabilities.

Using an expert system is simple, although the information needed to answer the questions it poses may not be available. Creating an expert system, as discussed in this paper, is not easy. As will become clear, it has not yet been decided whether it is worth the effort.

The major building blocks of an expert system such as FARMSYS are of three types: qualifiers, variables and choices. Qualifiers are the most commonly used component in FARMSYS. The following two rules are examples of rules composed only of qualifiers:

RULE NUMBER: 7

```
IF:     (1)  Ethnicity is Minangkabau
THEN:   (1)  Landowner is normally considered to be a corporate
             matrilineal clan.
    and (6)  Religion is Muslim
    and (9)  People value rice and no-till and water buffalo
```

```
Change:     If <I>, Then <T>, Else <E>, Note <N>, Reference <R>, Done
<ENTER>     for previous rule, for next rule:
```

Note: This information is based on 9 months' participant observation and other studies by Colfer (1986) in Pulai; and three studies in Koto Padang by Martha (1985), Murni (1985) and Agus (1984).

RULE NUMBER: 9

IF: (1) Ethnicity is Kenyan Dayak
THEN: (2) Land is viewed as abundant
(9) Most crops planted probably require minimal management
(10)Farm includes upland field

Press any key for more

It should be clear from these examples that qualifiers can be clear-cut (religion is **Muslim**) or fuzzy (most crops planted probably require **minimal management**). The system can incorporate quantifiable variables (domestic animals may include **chickens and pigs**) as well as qualitative attributes (ethnicity is symbolized by **female rice cultivation and male expedition making**).

The boldface parts of each sentence indicate the appropriate "value," selected from several as in the following:

RULE NUMBER: 221

IF:

Qualifier #76
People's diets are generally
1. protein poor
2. carbohydrate poor
3. vitamin poor
4. adequate

Enter number(s), NOT + number(s), New value <N>, Typo correction <T>, or to scroll, Help <H>, or just <ENTER> to cancel.

This rule shows how qualifiers appear on the screen when a new rule is being created. One can select from the values available or add a new value if necessary. All the qualifiers can be reviewed, one by one, at any time by scrolling with the arrow keys.

The second important component from which rules are constructed is **variables**. These were created to handle quantitative material but have been improved to include "string variables" (letters). Variables allow for rules requiring formulae.

RULE NUMBER: 220

IF (1) [PROPBOUGHTFOOD]>[PROPGARDFOOD]
+[PROPDRFLDFOOD]+[PROPHOMGARFOOD]

(2) People's diets are generally adequate

THEN:(1) Experimental crops should be those crops now grown for sale by the people -- probability = 75/100

Change: If <I>, Then <T>, Else <E>, Note <N>, Reference <R>, Done <ENTER> for previous rule, for next rule:

Number 1 in the "if" clause should read "if the proportion of bought food is greater than the sum of the proportion of food from orchards, food from dry fields and food from home gardens." The second component of the "if" clause is a qualifier.

The "then" clause introduces the third component: the **choice** recommendation). Each choice (and the probability of it being appropriate and accurate) is the end product provided to a user. A "choice" in a medical expert system might be a diagnosis (the probability of a particular disease, given the symptoms provided by the user). A choice in FARMSYS is a development-related recommendation.

The following rule shows how the choices appear on the right of the screen. Like the qualifiers, choices can be scrolled using the arrow keys. The rule also shows how the screen looks when one wants to edit a "then" clause by adding or changing a choice.

```
1. Experimental sites should include home gardens -- probability =
   90/100.

                                          8. Experimental sites should
                                             include home gardens
                                         10. Experimental crops should
                                             be food crops
                                         11. Experimental crops should
                                             be tree crops


                                         .
                                         <more text for this choice

Input choice number, New choice <N>, Typo correction <T>, cancel <ESC>,
Delete <D>, Find <F>, Help <H>, or press any other key for more choices?
```

In summary, the system takes site-specific information, collected in Indonesian villages, and forms it into "if-then" rules -- composed of qualifiers, variables and choices -- about people and agricultural research and development. These rules are designed to lead to development-oriented recommendations (choices) for scientists and policy-makers, which take people's behavior and beliefs into account. The result is rules that relate to nine Indonesian communities, but the authors hope to abstract some general principles about people and soil management after successfully "describing" these specific situations.

THE DATABASE

FARMSYS builds on ethnographic (and other) information collected on two projects. The information on the Minangkabau and on Javanese and Sundanese transmigrants was collected under the Tropsoils-Indonesia project between 1983 and 1986. Field research for FARMSYS was conducted in Sitiung, West Sumatra, a large "transmigration area." Major studies related to people were conducted in two indigenous Minangkabau communities (Koto Padang and Pulai) and in two transmigrant communities

(Aur Jaya and Piruko) with supplementary studies conducted in three more transmigrant communities (Sitiung II Blok D, Sitiung I Bloks B and D).

The information on the Dayaks of East Kalimantan was collected under a Man and Biosphere project entitled "Interactions Between People and Forests in East Kalimantan" in 1979 and 1980. The field research included in FARMSYS was conducted in Long Segar, a "resettlement village" 2 days and 1 night's river-boat ride from the provincial capital (Samarinda), and in Long Ampung, a remote community in the interior of Borneo, then accessible only by foot. Both communities were inhabited by Kenyah Dayaks.

In both projects, the information for the FARMSYS database was collected using two methods. The primary method was participant observation supplemented with focused quantitative studies. These studies were designed in response to our emerging understanding of local systems, both human and agroenvironmental.

Four year-long time-allocation studies were conducted in four communities using Johnson's (1975) method (see also Colfer 1983; Colfer, in press). Galileo studies on values and perceptions (See Woelfel and Fink, 1981) were conducted in two Dayak communities (Colfer, 1982b), three transmigrant communities, and one Minang community (Colfer et al., 1986 and 1987b). Studies of women's status and decision-making occurred in two Dayak communities, three transmigrant communities and one Minang village (Koto Padang and Pulai) and in two transmigrant communities (Aur Jaya and Piruko) with supplementary studies conducted in three transmigrant communities and one Minang village (Martha, 1985 and 1986; Elfina, 1985; Colfer et al., 1987a). A number of smaller, special-purpose studies were conducted as well (Chapman, 1984; Elfina, 1985; Evensen et al., 1985; Evensen, 1987; Kan, 1987; Naim and Herman, 1985).

Another component of the work included collaborative research with farming families. For 4 years the authors worked with 13 families designing and conducting experiments on upland fields (Colfer et al., 1984a; Wade et al., 1985; Colfer, 1987), one year working with families in a small catchment area, comparing soil-conservation techniques, and another year working with 10 farmers on home gardens, experimenting with organic fertilizers and studying cropping patterns and use of produce (Evensen, 1987), fish-pond management and forage-related practices (Evensen, 1987).

FARMSYS -- ITS CURRENT STATE

In designing this (fledgling) expert system, three important decisions were required early on: 1) for whom is the system being developed, 2) what "choices" should we provide, and 3) given these, how can the ethnographic information be structured so that differences that are most important arise early on in the rules? The experience in developing FARMSYS has been one of iterative oscillation in these decisions.

Users and Choices

The authors considered addressing the system to policy-makers, to scientists, to farmers, to extension agents and to co-team members. Farmers and extension agents were ruled out because of the shortage of electricity, computer equipment and computer skills in rural Indonesia. Scientists are the primary audience to whom the current system is addressed. Co-team members are seen as a subset of scientists, recognizing the goal of improving interdisciplinary communication. Policy-makers are potential secondary users. They are unlikely to know the answers to the questions that FARMSYS asks. Although this is, to some extent, true for scientists as well, they, by definition, have a mandate to find the answers. Further "oscillation" remains a possibility.

The question of what kinds of choices to provide to the user was, strangely, a difficult one as well. A primary strength, as well as a limitation, of anthropological information is its breadth. The holistic approach, a cornerstone of anthropology, means that to some extent one deals with everything. Which information would be most useful for practical, agricultural purposes? Would it be best to organize information so as to provide users with predictions about existing systems? Or would it be better to offer the user a prescription for something new, based on existing systems?

A starting point was prediction of the crops that would be grown on people's fields. This approach was too static and failed to tap some of the most useful information available. Yet trying to prescribe development strategies seemed too overwhelming at the beginning; describing what existed seemed a sufficiently momentous task.

However, as the authors progressed in the process of translating anthropological information into "if-then" statements, the idea of making these development-related prescriptions seemed increasingly feasible and desirable. From the point of view of agricultural development, the relevance of existing cropping patterns lies in making decisions about what future cropping patterns to study, develop and extend. So, at this stage the choices prescribe particular courses of action for users (the scientists). More will be said on the kinds of choices offered. But to convey partially the iterative nature of the FARMSYS development process, the structure of the "if-then" rules will be covered first.

The Structure of the Rules

Two characteristics emerged immediately as critical for differentiating among the farmers being worked with. Ethnicity and location each significantly affected agricultural practices. Therefore, a series of rules identifying relevant factors about ethnicity and locations of study appears early in FARMSYS.

Since the information is, to some degree, site specific, it was necessary to indicate how such information is relevant (or irrelevant) in other areas. FARMSYS' first rules appear as a series that provides

probabilities for a choice: "Results of this system should be applicable." Rule 1, for instance, is

IF: Location is in Bali, Java or arid Outer Islands
THEN: Results of this system should be applicable -- probability = 50%

Rule 5 says

IF: Location is in the Sitiung area of West Sumatra
THEN: Results of this system should be applicable -- probability = 50%

The importance of ethnic differences also had to come up early in the system. Rule 11 is provided as an example in its current draft form:

IF: Ethnicity is Javanese transmigrant
THEN: Landowner is normally considered to be a male household head
and Land is viewed as very limited
and Rights to land are traditionally certified and private
and Women's agricultural labor is recognized as necessary but not preferred
and Ethnicity is symbolized by farming and small-scale female trade
and World view is hierarchical and authoritarian
and Domestic animals may include < 2 cows and goats and chickens and 2 or more cattle
and Most crops planted probably require intensive management
and People value fertilizer and hoeing and cattle

Rules 7 and 9, above, provide comparable data on two other ethnic groups. In rule 7, for instance, it is uncertain whether the qualifiers "women's agricultural labor is recognized as essential" and "most crops planted probably require minimal management" apply to Minang generally or only to those in the Sitiung area or to Minang in other areas like Sitiung as well.

Questions such as these will be investigated through the literature initially, and perhaps ultimately through a workshop of agricultural anthropologists with relevant research experience. It is hoped (and anticipated) that, in compiling data on these quite different farming systems, general principles will emerge that relate to soil management and that transcend locality. Each of the remaining general topics must be dealt with to some extent for each ethnic group.

It still has not been decided whether location or ethnicity should come first, since they seem to be equally important. Since ethnicity has often been ignored in agricultural research, it is currently placed first. However, ethnicity is an unpopular topic, like tribalism, in modern states. So putting it in a place of preeminence could adversely affect the use of the system. Within the rules related to ethnicity, the Outer Island ethnic groups (Minang and Dayaks) have been chosen first to highlight the significant differences of their systems vis-a-vis the better-known Javanese and Sundanese systems.

Given these locational and ethnic differentiations, next comes a series of topics that vary along these dimensions and that relate to

agricultural research and development. The topics so far identified as relevant are discussed briefly, roughly in the order they are addressed in FARMSYS, and examples of rules dealing with each of these topics are provided. All rules in this system contain "qualifiers". Rule 101 provides an example of use of a "variable". Rules 1, 5, 138 and 154 include "choices" and probabilities that the choices (recommendations) are appropriate. The interconnections among these factors preclude strict ordering.

Crops grown. Different ethnic groups, even in the same locations, express preference for, have experience with and continue to grow different crops (cv. Evensen, 1987; Colfer et al., in press; Colfer, 1983). Their interest in various crops differs based on such factors as risk, labor requirements, prices, knowledge of management and land availability.

Rule 22

IF: Ethnicity is Javanese transmigrant
and Farm includes paddy field
and Crops are vegetables

THEN: Vegetables may include swamp cabbage

Land use. There are differences in land use, depending on whether the farmers are indigenous Outer Islanders who practice extensive land-use methods or transmigrants from the densely populated island of Java. The former select lands from unused forested areas, appropriate to particular crops.

Rule 34

IF: Location is in Long Segar, East Kalimantan
and Farm includes upland field
and Agricultural labor is sufficient or abundant

THEN: Field is > 1 ha - 5 ha
and Field is newly cut from forest > 30 years old and planted

Transmigrants tailor their cropping and management patterns to the small, permanent plots they have been given by the government (Fulcher, 1982). In all ethnic groups, different cropping patterns and management strategies are used, depending on the kind of field in question (paddy field, upland rice field, orchard or home garden; see Colfer et al., in press).

Division of labor. Although both men and women in all four ethnic groups are involved in agriculture, there are significant differences among them. Among the Dayaks, women are seen as the primary cultivators of rice (the most important crop; Colfer, 1981c, 1983 and 1985). Rubber, an important crop for the Minang in the Sitiung area, is seen as primarily a men's crop for management purposes, but more than half the rubber is owned by women. Home gardens are seen as primarily women's domain by all the ethnic groups studied (Colfer et al., 1986). The

Javanese and Sundanese view farming as ideally a man's occupation, though women "help out" to a substantial degree.

Rule 101

IF: Location is in Piruko, West Sumatra

THEN: [FEMAGLAB] is given the value of 9
and [MALAGLAB] is given the value of 16
and [FEMMARKET] is given the value of 1
and [MALMARKET] is given the value of 0
and [FEMHOE] is given the value of 1
and [MALHOE] is given the value of 8
and [FEMWAGLAB] is given the value of 4
and [MALWAGLAB] is given the value of 8
and [HOMGARTIME] is given the value of 5
and [DRYFLDTIME is given the value of 11
and [SAWAHTIME] is given the value of 8
and [FEMCUTNCARRY] is given the value of 4
and [MALCUTNCARRY] is given the value of 4

(See Colfer et al., 1984b; or Colfer 1981a for Dayaks.)

Risks. Risk varies by location and crop. Ethnic groups differ in their willingness to take risks. Therefore, different risk-management strategies are used in different locations. Where unpredictable rainfall makes drought and flooding alternate risks in the same area, the Dayaks alternate two fields (one on high ground and one on a riverbank; Colfer, 1983). In the Sitiung area, one response to the multiplicity of agricultural risks is to diversify crops (Colfer et al., in press).

Rule 119

IF: Location is in the Sitiung area of West Sumatra
and Field crop is mung beans or corn or chili

THEN: Risks include insufficient fertility of soil and aluminum toxicity

Animals. In each of the four ethnic groups, animal ownership differs. In the villages where the authors worked, all own chickens, if possible, but only the Minang keep water buffalo, only the Dayaks keep pigs, and only the Javanese keep cattle, in general (see, for example, Colfer et al., 1980). Differing attitudes and behavior toward manure have important agricultural implications where cash is in short supply to purchase fertilizer.

Rule 143

IF: Ethnicity is Javanese transmigrant or Sundanese transmigrant
and Animals may include cattle or goats
and Farm includes home garden

THEN: People use barnyard manure (Agus et al., 1987)

Land preparation. The Javanese and Sundanese, used to extreme land shortage, are ready and willing to hoe and plow and intensively till their lands — to the extent of their physical capabilities. Outer Island farmers find only minimal amounts of hoeing acceptable. They dibble-plant upland rice and rarely plant any of the other field crops that would require hoeing or plowing unless the anticipated profit is great and their financial situation allows risk-taking (see Colfer, 1983; Colfer et al., 1984a; Wade et al., 1985).

Rule 138

IF: Location is in Koto Padang, West Sumatra; or Pulai, West Sumatra; or Long Segar, East Kalimantan; or Long Ampung, East Kalimantan
And Land preparation is dibble stick
And People value no-till

THEN: Experiments on intensive tillage methods are appropriate -- probability = 5%

Fertilizer/inputs. Both willingness and capacity to fertilize crops vary. Outer Island farmers show less interest in fertilizers than do farmers from Java (Colfer et al., 1986 and 1987b). Even willing farmers have recurrent problems of cash availability for purchased fertilizers. Javanese farmers with cattle make regular use of their manure as a fertilizer (Agus et al., 1987). Minang farmers never use the manure from their water buffalo as a fertilizer; they burn it as mosquito repellent for the beasts.

Rule 154

IF: Fertilizer is a kind requiring incorporation
and Land preparation is hoeing
and Most crops planted probably require intensive management

THEN: Experiments on intensive tillage methods are appropriate -- probability = 80%
And Experiments on levels and kinds of commercial fertilizer are appropriate -- probability = 80%

Income. People's incomes influence their willingness and ability to risk cash on agricultural inputs. In places like Long Ampung, where there are no regular sources of income or agricultural inputs, agricultural improvements must capitalize on such strategies as alternate tillage methods or use of indigenous materials for organic matter.

Rule 146

IF: Location is in Long Ampung, East Kalimantan

THEN: Money is rarely used and in short supply
and Selling produce is difficult and disvalued and rare
and Access to location is difficult on foot and expensive by small plane

These remain important in the other areas, simply because of the low levels of income available to most farmers.

Production. Rice-production levels in Kalimantan influence people's interest in clearing forest for new fields (Colfer, 1982a). Production levels are a major factor in whether transmigrants are trying other crops. Increasing production is viewed as irrelevant for most crops by farmers in purely subsistence areas such as Long Ampung or for subsistence such as swamp cabbage or cassava leaves in other areas.

IF: Location is in a difficult place to reach
and Money is rarely used
and Selling produce is difficult
and Nutritional status is adequate

THEN: People's agricultural goals are not to maximize production

Such differences must be taken into account in moderating the tendency for some agricultural scientists to focus only on increasing production. Farmers' interest in production is closely tied to marketing potential.

Nutrition. Nutritional status in all the groups with access to markets is marginally adequate. It may actually be adequate in Long Ampung, though the evidence is only observational and short term (see Colfer 1981a and 1981b). It almost certainly declined with access to markets in Long Segar, relative to Long Ampung. Differing crop marketing and dietary patterns among the different groups suggest that a variety of strategies for enhancing nutritional status by agricultural means is in order.

Rule 168

IF: Location is in the Sitiung area of West Sumatra
and Ethnicity is Javanese transmigrant
and Field crop is upland rice or cassava or paddy rice

THEN: This food is a staple

The Structure of the Choices

Just as the rules are organized into a hierarchical structure to some extent, it makes sense to organize the choices (recommendations) in some way. EXSYS (the program) begins with the first choice and tries, by going through the rules, to provide the user with that recommendation. It then goes on to the next choice and does the same thing.

In this case, the choices are recommendations designed for agricultural scientists and are organized into a logical order according to their decision needs. It is assumed that the scientists may be working with farmers and that they are trying to design their experiments in such a way that their results will have the maximum probability of being usable by farmers. The user is allowed to specify the scientist's or policy-maker's goal for the research -- whether it include increased production only, equity only, production and equity, improved nutrition and(or)

increased financial security for all family members or for only the head of the household.

The first series of choices, or recommendations, relates to which farmers the scientist should be working with. These choices specify female farmers, male farmers, both sexes, a fair mix of ethnic groups and a fair mix of clans resident in the area. This should serve to widen the perspective of users, since there is a tendency to work with male farmers from Indonesia's dominant ethnic group.

The second series of choices helps the scientist choose a type of field. The choices at this stage are upland fields, paddy fields and home gardens. Again, this may serve to widen the realm of agricultural endeavor, since very little research is currently done on home gardens. Home gardens already supply large portions of income and food for transmigrants (particularly in the early years of settlement); they represent the "best bet" for improved nutrition in some areas, and they hold much potential for working with female farmers (Colfer et al., 1985).

Our third series of choices recommends crops to be used in experiments. Most agricultural experiments in Indonesia are performed on field crops. Yet in the infertile areas of the Outer Island, tree crops appear much better adapted to local conditions; they can sometimes provide a source of cash and require less labor. Another neglected kind of crop with important nutritional advantages is vegetables. Pasture and fodder crops may save transmigrant cattle owners considerable time (given their cut-and-carry feeding system) as well as supplying a source of organic matter (a valuable soil amendment).

The integral role of rice cultivation in Dayak life would make the adoption of alternate field crops less likely than for the Javanese, who show interest in a variety of crops. Experiments using rubber trees as a crop would make more sense among ethnic groups with experience growing, processing and selling that crop. In the Sitiung area, rubber growing has taken on symbolic value as an ethnic marker, making it less attractive to non-Minang farmers.

The last series in the list of choices relates to specific kinds of experiments appropriate under differing conditions. Some examples follow:

Given the lack of interest and experience of the Minang and Dayaks with hoeing upland field crops, experiments that require incorporation of fertilizers or lime prior to planting are unlikely to lead to popular technologies; with the transmigrants, however, such experiments could yield a high adoption payoff (if funds were available for purchase of inputs). Research on minimum tillage would at least initially be of little interest to transmigrants whereas Outer Island farmers could be expected to take to it immediately.

Experiments and technologies requiring manure use among the Dayaks would probably be of little value, since Dayaks express extreme revulsion at

the thought of handling manure. Javanese cattle owners, however, handle manure regularly and would benefit from such experiments.

Experiments on spacing of food crops may best be done with female farmers since they are often in charge of planting. Similarly, studies of herbicides might best be done with women, those who do the work often have the most motivation to reduce labor input. Conversely, experiments on land preparation or techniques for felling large trees (in land clearing) are, in most cases, most appropriate for male collaborators.

All of these choices must, of course, be evaluated by the scientists themselves, taking into account other more agroecological factors as well as their own areas of expertise. The recommendations are designed to mirror what an anthropologist (with some familiarity with things agricultural) would suggest, based on fairly intimate knowledge of these farming systems.

SUMMARY

This endeavor is at a very early stage, and obviously a great deal of work remains to be done. It remains to be determined if the relevant aspects of local farming systems can be effectively depicted within this "if-then" framework. Information on various locations and ethnic groups is being incorporated in the search for principles applicable in other, quite divergent areas.

The most fundamental problems encountered with the approach include the following:

1. EXSYS uses the qualifiers and variables provided in the if-then rules to determine what information it needs from a user. It then asks the user for that information. In FARMSYS, as well as ACID4, the answers to many of the questions are unlikely to be readily available.

   In FARMSYS, there is quite a bit of quantitative information on time allocation and on dietary patterns of different ethnic groups. As the system now stands, it asks users questions like "what percentage of total adult time is devoted to agricultural activity in the home garden?" or "what proportion of food items other than rice are green leafy vegetables?" No one has answers to such questions for the vast majority of rural villages.

   One possible solution is to delete such specific quantified data and rephrase the information in more qualitative terms (so that a question would be phrased generally; "do people eat a little, an average amount or a lot of green leafy vegetables?")

2. Specific and extensive information on the Sitiung area of West Sumatra and on two areas in East Kalimantan is available. However, there is currently no way to extrapolate from such specific information to other areas that undoubtedly have a lot in common with these locations.

A possible solution to this problem would be to develop analogies within the system. Rules would have to be developed to guide users to a data set that would be the closest to their case: "If your case is in a very remote area, Then select location is Long Ampung," or "If your case includes people from a densely populated rural area, Then select ethnicity is Javanese transmigrant."

3. The probabilities that are assigned to the choices (recommendations) are currently determined simply by qualitative "feel" -- pure judgment, largely on Colfer's part. A more systematic method is important in the long run. Certainly some effort needs to be devoted to developing a consensus among the authors and, ideally, some other social scientist with experience in Indonesia.

4. The system works best when rules occur in a hierarchical manner, with the most important factors/differentiations occurring early on. The four ethnic groups, for instance, are on the same level of importance; yet an arbitrary selection must be made simply because the system operates in order. Arbitrary ordering choices have had to be made at every level within the system.

   No real solution seems probable, and the importance of the problem is unclear.

To end on a positive note, the aspects of the system that are appealing include the following:

- It can handle large quantities of complex data (qualitative as well as quantitative) and incorporate them quickly into a chain of links leading to a recommendation.

- It provides a mechanism whereby someone from another discipline can get an "expert opinion" -- an answer -- without having to learn a whole new set of jargon and methods. The system allows the user to ask how the answer was derived (by displaying the rules used).

- It seems to offer a possible avenue for feeding village-based information to policy and decision-making centers of government.

We continue to think "expert systems" hold some promise for making "people factors" more accessible and perhaps thereby better integrated into research and development.

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INTERVARIETAL SELECTION METHOD IN INTERCROPPING SYSTEMS IN HAITI

Sorel Jacques and Robert Bacon[1]

INTRODUCTION

Intercropping is a well-known practice among small farmers in tropical and subtropical countries. It consists of growing two or more crops simultaneously on the same land. Intensification of crop production, then, occurs in time and space due to a certain degree of competition during part of, or the whole, vegetative cycle of the plants. In several countries of Africa, Central America and the Caribbean region, a significant amount of the total food production comes from crops grown in intercropping systems.

The national and international development projects, which began in the second half of this century in developing countries, did not focus on development of appropriate technologies to increase the net income of small farmers practicing intercropping. The promoters of those projects thought that they could import those technologies from more advanced countries. Only recently have researchers started exploring the potential of the traditional systems to improve crop yield and increase farmer's net income.

This study used two crops, corn and beans, to test a farmer's method of variety selection in an intercropping system.

Intercropping in Latin America

Different intercropping systems are practiced among tropical countries. They result from the low level of investment in agriculture, the need to minimize the risk in adverse conditions and, finally, the need to participate in the marketing economy (Jacques, 1983).

Small farmers in Central America and the Caribbean use several intensive land use systems to produce the food needed for consumption. In these systems, labor is supplied by their own families; the crop varieties are not uniform and are called "local varieties." Generally, they do not use improved seeds, pesticides or fertilizers. The yields are low, and the family net income is below $300 a year.

In several Central American countries, intercropping is the main method of crop production. In the Alajuela region of Costa Rica, intercropping includes pineapple/pepino, pineapple/bean, pineapple/cassava, etc. Northwest Brazil is famous for its sisal/corn, small grain/cucurbitaceae, cotton/corn/beans and higuerilla/bean/corn intercrops.

[1]Agronomy Dept., University of Arkansas, Fayetteville, AR 72701, U.S.A.

In the northwest region of Haiti, four crops with different vegetative cycles are grown together; they are banana/cassava/corn/bean. Banana is planted first, followed 1 month later by cassava, which precedes by one or two weeks the corn and beans. Beans are harvested 2 1/2 months after planting. Then the corn is picked 4 months after planting, followed by cassava 10 to 11 months after planting. The banana remains in the field for 3 years, thereby completing the cycle.

In the southeast region of Haiti, where this study was conducted, the most common intercropping systems are yam/corn/bean, corn/bean, cassava/corn/cowpea, sweet potato/corn and peanut/corn.

Framework of the Agricultural Trials in the Jacmel District (Southeast Haiti)

The intercropping system presented in this study is corn/bean. The main objective of this work was to identify, develop and apply new technological alternatives capable of improving yield potential in the corn/bean intercropping system. The farmer's small plot was used as the site of the experiment. Thus, the natural environmental conditions and the local crop management remained the same for the testing of such different production factors as density, variety and fertilization. The effect of one factor (simple) or of several factors (factorial) was studied by comparing them to the farmer's traditional practices.

The farmer's participation for personal control and as an extension teaching tool is very important in attaining the desired agricultural development objectives (Tardieu, 1980). This idea was reinforced by Bailly et al. (1980), who stated, "The research results in production systems, need not only to be possible agronomically and economically, but also practically." The techniques tested and developed must be appropriate to the farmers' local infrastructure.

METHODOLOGY

Survey in the Zone and Genetic Material Identification

The initial phase of this method is the collection of data to identify the socioecological environment and the economic system related to it. This allows the investigator to recognize the limitations, weaknesses and constraints attached to the local system. Once the characteristics of the zone are well defined, the local germplasm is consulted to select varieties adaptable to such environmental conditions.

This study was conducted at Haut Cap Rouge in the Jacmel District of southeast Haiti from February 1984 to February 1986. This is a hilly area at 600-800 m above sea level. The annual rainfall of 2500-3000 mm is well distributed over the two cropping seasons per year. The first starts in February and ends in June; the second extends from August until December. In this region the main crops are corn, bean, yam and cassava, which are often planted in intercropping systems, and the two most common systems are corn/bean and yam/corn/bean. The latter is especially practiced in the February-to-June season. The average yields

for these different crops are 28,300 kg/ha for yam, 1668 kg/ha for corn and 240 kg/ha for bean.

Since corn and bean were the main crops for Haut Cap Rouge, they were used in the intercropping study. The three corn varieties tested were 'La Maquina 7828', 'La Maquina 7928' and 'Les Anglais.' They were developed in Haiti by the "Centro International de Mejoramiento de Maiz y Trigo" (CIMMYT) research group on the Levy experimental station near Les Cayes in south Haiti. The bean varieties used were 'Damien 544,' 'Damien 450' and 'Tamazulapa,' developed at Damien, Haiti, by the University's FAMV (Faculte d'Agronomie et de Medecine Veterinaire) research and 'Salagnac 86' distributed by the researchers at the Madian Salagnac research station.

Variety Trials

As Tardieu (1980) stated, trials were established using local practices with variety as the experimental variable. The farmer's planting method was not modified.

In August 1984, two groups of trials were established:

1. Trials comparing the four corn varieties (including the local variety) grown with the local bean variety. Therefore, the four treatments for this trial were local bean/local corn, local bean/La Maquina 7828 corn, local bean/La Maquina 7928 corn and local bean/Les Anglais corn. The treatments are randomized in one block with two repetitions. Data were collected in 13 different trials.

2. Trials comparing five bean varieties (local variety included) planted with the local corn were also established. The treatments were local corn/local bean, local corn/Salagnac 86 bean, local corn/Tamazulapa bean, local corn/Damien 450 bean and local corn/Damien 544 bean.

A complete block design with two replications was used, and data were collected in 13 trials. The treatments were evaluated for

1. the physiological development of the plant in the intercropping system,

2. the yield of each variety expressed in kilograms per hectare and

3. net benefits calculated using the partial budget method of Perrin et al. (1979), which utilizes input costs as well as current prices of each crop to compute production value per unit of land.

Interaction Trials

The previous experiment of this investigation identified La Maquina 7827 and Les Anglais as the two superior corn varieties and Salagnac 86 and

Tamazulapa as the two best bean varieties. The next step was to study the interaction of those varieties in intercropping. The local conditions and the farmer's practice remained the same. The selected varieties were combined and compared to the control (local corn/local bean).

Two types of interaction trials were used for the comparison:

Type I: local corn/local bean, local corn/Tamazulapa bean, local corn/Salagnac 86 bean, Les Anglais corn/local bean, Les Anglais corn/Tamazulapa bean and Les Anglais corn/Salagnac 86 bean.

Type II: local corn/local bean, local corn/Tamazulapa bean, local corn/Salagnac 86 bean, La Maquina 7827 corn/local bean, La Maquina 7827 corn/Tamazulapa bean and La Maquina 7827 corn/Salagnac 86 bean.

The experimental design used was a split plot with corn in the main plots and bean the subplots. The best associations were selected in type I and II, from 14 and 16 trials of each type, respectively.

Comparison Trials

In the comparison trials, the intercropping was selected with the agricultural practices remaining the same. The associations selected in type I and II were compared with the control in 36 trials. The treatments were local corn/local bean, local corn/Tamazulapa bean and La Maquina 7827 corn/Salagnac 86 Bean.

RESULTS AND DISCUSSIONS

The results are expressed in yields for the variety trials and net return for interaction and comparison trials.

Variety Trials

Statistically different yields were obtained among corn varieties. The two highest yielding corn varieties were the local variety and La Maquina 7828.

* Bean yields showed significant differences among varieties when using analysis of variance. The varieties Tamazulapa and Salagnac 86 were both significantly higher yielding than the local check.

Interaction Trials

In the interaction trials where corn was the main plot, the yield of the local corn was not significantly different from that of La Maquina 7827, and both were superior to Les Anglais. The intercropping system with the highest net return for Type I was local corn/Tamazulapa and for Type II was La Maquina 7827/Salagnac 86.

Comparison Trials

In the comparison trials, the local corn/Tamazulapa intercropping system had a significantly higher net benefit than La Maquina 7827/Salagnac even though the net returns were similar in the two interaction trials. Therefore, in the comparison trials, the local corn/Tamazulapa has been selected. This system allows nearly a two-fold increase of the local check net return.

CONCLUSION

The intervarietal selection method described in this study can be used to identify a more productive system of intercropping for an ecosystem. It requires a period of three growing seasons or 1 1/2 years in Southeast Haiti.

* In this study, the local corn/Tamazulapa bean system was selected as the most efficient in land use. This system's return per hectare was nearly twice as great as the local check.

* Verification trials must be run before adoption of the new practice.

* Intervarietal selection must be conducted for further improvement of the system by increasing yield of the local corn.

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LABOR MANAGEMENT EFFECTS ON THE RELATIVE PROFITABILITY OF ALTERNATIVE MILLET-COVPEA INTERCROP SYSTEMS IN NIGER

M. A. Krause, K. Maliki, K. C. Reddy, R. R. Deuson and M. Issa[1]

INTRODUCTION

Increasing food production is an essential goal of the government of Niger, a West African country located to the north of Benin and Nigeria. Only about 24% of Niger receives enough rainfall to grow crops, and only half of this is considered cultivable (Club du Sahel, 1982). Most of the cultivable area lies in the Sudano-Sahelian zone, which has an average rainfall of 350 mm to 700 mm and frequent droughts. Most of the soils in the cultivable zone consist of at least 90% sand and less than 0.3% organic matter, so they have minimal capacity for holding water and plant nutrients. Soil nutrient levels are generally low and declining.

In 1984, agronomists and agricultural economists at the Institut National de Recherches Agronomiques du Niger (INRAN) initiated an intercrop-production-systems research program (Reddy and Gonda, 1985; Reddy and Oumara, 1985; Ly et al., 1986). A 1982 survey of 348 farms in the Madarounfa arrondissement (one of the three regions chosen by INRAN for farming systems research; an arrondissement is a main subdivision of a department in the Nigerien administration) showed that 79% of the fields were intercropped (Swinton et al., 1984). The primary crop associations included millet and cowpeas, sometimes combined with sorghum and peanuts. Guided by these observations, agronomists at INRAN conducted on-station research trials to evaluate alternative plant varieties, plant spacings and fertilizer application rates for inter-cropped millet and cowpeas.

ON-FARM TRIALS: 1985 AND 1986

In 1985, the most promising of the plant varieties, plant spacings and fertilizer application rates were included in an on-farm trial in which the first treatment represents traditional practices and other treatments each introduce a new technology (Appendix Table A-l). The second treatment introduces an improved millet variety. The third treatment includes the improved variety and increased plant densities. The fourth treatment includes the improved variety and increased plant densities and introduces fertilizer applications.

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[1]Mark Krause is an agricultural economist on the staff at Purdue University and currently with the Niger Cereals Research Project in Maradi, Niger. Maliki Kadi and Issa Mahamane are agricultural economists in the Department of Rural Economic Research (DECOR) at the National Institute of Agronomic Research of Niger (INRAN). Chandra Reddy is an agronomist on the staff of Alabama A&M University and currently with the Niger Cereals Research Project. Robert Deuson is an agricultural economist on the staff at Purdue University and, until February 1987, he was the senior economist on the Niger Cereals Research Project, in Niamey, Niger.

The agronomic results from 1985 and 1986 (Table 1) indicated a significant yield response by millet and cowpeas to the application of fertilizer (included in the fourth treatment) and a significant yield response by cowpeas to increased density (introduced in the third treatment).

Budget analyses of the 1986 data (Tables 2 and 3) indicate substantial increases in returns to labor and management (measured by gross revenues minus cash costs) for the increased density (treatment 3) and fertilizer applications (treatment 4). However, labor requirements were also much higher for treatments 3 and 4 than for treatments 1 and 2 (Appendix Table A-2). As a result, net cash returns per day worked and returns to management (measured by gross revenue minus cash costs and the opportunity cost of labor) were often lower for treatments 3 and 4 than for treatments 1 and 2. Based on the prevailing daily wage rate, the opportunity cost of labor considerably outweighed cash costs in the calculation of returns to management. Yet participating farmers rarely hired labor, and surveys in 1984 and 1985 indicated few opportunities to earn off-farm income (Swinton, 1985 and unpublished data). This uncertainty regarding the value of labor has made it difficult to draw clear conclusions from the budget analyses.

LINEAR PROGRAMMING

The present analysis uses linear programming to evaluate the effects of labor availability and allocation on the choice of crop technology. In this application, linear programming selects a set of intercropped millet-cowpea production activities that maximize total net cash revenue subject to land, labor-time and consumption constraints. It is hypothesized that labor constraints during critical periods of the crop season and the allocation of scarce labor will largely determine the choice of crop technology. It also is hypothesized that an analysis of the effects of labor allocation on the choice of technology will provide appropriate indications of labor value in crop production.

METHODOLOGY

The linear-programming model used in this analysis is based on 1984 farm survey data and 1986 on-farm trial data from two villages in the arrondissement of Madarounfa, situated in southcentral Niger. The villages of Maiguéro and Rigial Oubandawaki are both predominantly Hausa villages with sandy soils. However, Maiguéro lies in a river valley that has a high water table and more fertile soils, so it is more densely settled than Rigial Oubandawaki.

The linear-programming model is a simple representation of technology performance on Madarounfa farms. Only millet and cowpea production are represented, whereas sorghum and peanuts are also important crops. However, INRAN does not yet have sufficient data relating to labor requirements and effects of operation dates for other crops to accurately represent them. Household, nonfarm activities and livestock management are not represented, except to the extent that they reduce

labor-time availability for field work. The effects of labor management on the choice of crop-production technology are evaluated by using various assumptions for family labor availability and by allowing labor to be hired.

The model of intercropped millet and cowpea production represents the critical first 2 months of the crop season, with a series of eight high-moisture periods (H1-H8) alternating with seven low-moisture periods (S1-S7). The high-moisture periods are 2 days long, immediately following a rain sufficient for planting (usually 10 mm or more). Although the periods between planting rains are highly variable, in 1985 and 1986 the planting rains in the two Madarounfa villages were on average about 7 days apart. Therefore, the initial model assumes that the seven low-moisture periods are each 5 days long.

Planting is permitted only in the high-moisture periods following a planting rain. Millet may be planted in the first two such periods (H1 and H2). Cowpeas may be planted in the third through the fifth high-moisture periods (H3, H4 and H5). Following the on-farm trial protocol, cowpea planting must follow millet planting by at least 2 weeks to give the millet sufficient time to establish itself without competition from the cowpeas. It is assumed in the initial model that 10% of the planted area must be replanted in the next high-moisture period. More substantial replanting requirements are always a possibility in Niger due to high soil temperatures, frequent delays before the next rain, sandstorms and occasional rodent problems. Therefore, the effects of assuming 20% and 33% replanting requirements are also examined.

Weeding may be done either in a high- or low-moisture period. The first weeding is permitted in the third through the sixth high-moisture periods (H3, H4, H5 and H6) and in the succeeding low-moisture periods (S3, S4, S5 and S6). The second weeding is assumed to follow 4 weeks after the first weeding. The two urea applications are made in the high-moisture period immediately following each weeding.

YIELD ADJUSTMENT COEFFICIENTS

A multiple-linear regression analysis of 1986 data showed a tendency for millet and cowpea yields to decline as planting and first weeding dates were delayed at Maiguéro and Rigial Oubandawaki (Appendix Tables A-3 and A-4). Regression coefficients for the effect of the millet-planting date on millet yield were significant at a 5% level of confidence for each treatment. Regression coefficients for the effects of the number of days before first weeding on millet yields, cowpea planting data on cowpea yields and days before first weeding on cowpea yields were not statistically significant but are supported by on-station trial results. However, no relationship was found between cowpea planting data and cowpea yield for the third treatment.

Based on the regression results for the effect of planting and first weeding dates on millet and cowpea yields, yield adjustment coefficients were calculated for each possible combination of planting and first weeding periods. Twenty-eight alternative production activities are

included in the model for each treatment. Separate versions of the model were created for Maiguéro and Rigial Oubandawaki, based on the average yields for each village.

Other activities included in the model are millet sales, cowpea sales, millet consumption, cowpea consumption and millet purchases for consumption (in case the millet consumption constraint cannot be met from on-farm production). Millet is sold for 30 francs CFA/kg and cowpeas are sold for 80 francs CFA/kg, which were the respective harvest-time prices at a nearby village market (Gabi). Millet may be purchased for 30 francs in the model. Millet and cowpea consumption is not given a value. The consumption requirements of 220 kg of millet and 30 kg of cowpea per person (Arnould, 1986; Stoop, 1981) only reduce crop sales.

The net cash revenue function includes the prices for millet sales, cowpea sales and millet purchases for consumption, plus the costs for each production activity. The improved seed and fertilizer are valued at their official Nigerien Ministry of Agriculture prices for 1986. Extensions of the model include a cost of capital for improved seed and fertilizer purchases, since money must either be borrowed or diverted from other potential uses to purchase them. Following the recommendation of Perrin et al. (1976), results using a 40% and a 100% annual cost of capital are compared to the initial model results. It is assumed that money is borrowed or diverted for 6 months, so the effective costs of capital are 20% and 50%.

Land and family labor constraints for the Maiguéro and Rigial Oubandawaki model versions are based on a survey conducted by INRAN in 1984 (Swinton, 1985). The average cultivated farm area for Maiguéro is 3.84 ha, and the average for Rigial Oubandawaki is 8.06 ha. Maiguéro has an average of 1.3 adult men, 1.5 adult women, 0.4 adolescents (10-13 years) and 2.2 children (0-9 years) per farm. Rigial Oubandawaki has an average of 2.4 adult men, 2.6 adult women, 0.7 adolescents (10-13 years) and 3.7 children (0-9 years) per farm. The total number of men, women and adolescents determines labor availability during the high-moisture periods. Labor availability in other periods is determined by adding the number of men to 60% of the number of women and 50% of the number of adolescents (the same coefficients were used to calculate labor requirements by operation). The initial model assumes that farmers are willing to do 6 days of field work per week. Extensions of the model examine the effect of 5 and 7 days of field work per week.

Labor hiring is considered in extensions of the model. Since hired labor is rarely available during the initial planting periods, labor hiring is considered first for all periods, then only for periods following the initial period for planting cowpeas. A 20% or 50% capital cost is included in all of the analyses that consider hiring labor.

The sensitivity of the choice of crop technology to risk perceptions is analyzed by substituting the average crop yields for the individual plots with the lowest 25% of gross revenue per hectare for the average yields for all plots. The effects of assuming these reduced yields are evaluated for the case of 6 days of field work per week, once without a cost of capital, and again with a 50% cost of capital.

RESULTS AND DISCUSSION

The linear-programming analysis shows that yield penalties for delays in completing planting and first weeding operations reduce the optimal land area for the technology that produces the highest yields but is the most labor intensive (treatment 4). In the initial model, which assumes 6 days per week for field work and no cost of capital, 25% of the fields at Maiguéro are planted to the second treatment, and 75% are planted to the fourth treatment (Table 4). At Rigial Oubandawaki, 64% of the fields are planted to the second treatment, 9% are planted to the third treatment, and 27% are planted to the fourth treatment. Most of the available labor in the early periods of the crop season is allocated to the fourth treatment (Table 5), but after the fourth humid period (H4), the model shifts much of the available labor to less-intensive treatments.

Shadow Price of Labor

The results for the initial model also demonstrate that labor is a valuable commodity during planting and first weeding periods (Table 6). At both villages the implicit value (shadow price) of another available person-day of labor for every cowpea planting and first weeding period is greater than the 600-franc daily wage rate. In several instances, the implicit value of another person-day of labor is more than double the daily wage rate. At Maiguero the implicit value of labor for the first millet planting (HI) is also greater than the daily wage rate, assuming 6 or 7 days of field work, per week.

Labor Availability and Treatment Choice

The number of days per week assumed available for field work has a strong influence on the choice of treatments by the model. This assumption is doubly important because economic theory suggests that the availability of labor will increase if the remuneration to labor increases, whereas many anthropologists argue that in primarily subsistence agricultural societies the amount of time worked does not follow standard economic theory (Sahlins, 1972; Arnould, 1986). Thus, economists might argue that if the most labor-intensive technology (treatment 4) is sufficiently profitable, farmers will work up to 7 days a week in order to use it. The anthropological argument is that economic objectives in subsistence agricultural societies are defined primarily by a person's social relationships and obligations within the village. As a result, few farmers have sufficient incentives to regularly work more than 5 full days per week. In either case, farmers are observed to frequently take time away from field work to go to market, go to the mosque, prepare food, talk to friends, look after children and rest at home.

A reduction in labor availability from 6 to 5 days per week greatly reduces the proportion of fields the model plants with the fourth treatment (Table 4). At Maiguéro this reduction in labor availability reduces the proportion of fields planted to the fourth treatment from 75% to 39%. At Rigial Oubandawaki the reduction in labor availability reduces the proportion of fields planted to the fourth treatment from

21% to 5%. On the other hand, an increase in labor availability from 6 to 7 days per week raises the proportion of fields planted to the fourth treatment to 100% at Maiguero and 42% at Rigial Oubandawaki (Table 4).

Replanting Requirements

Greater replanting requirements significantly reduce the proportion of fields the model plants with the fourth treatment at Maiguéro and the proportion of fields the model plants with the third and fourth treatments at Rigial Oubandawaki (Table 7). Increasing the replanting requirements from 10% to 33% at Maiguéro reduces the proportion of fields planted to the fourth treatment from 75% to 64%. At Rigial Oubandawaki, the proportion of fields planted to the third treatment falls from 9% to 5%, and the proportion of fields planted to the fourth treatment falls from 27% to 24% as replanting requirements are increased from 10% to 33%.

Capital Costs

Capital costs seem to have little effect on the choice of technology when labor availability is a serious constraint, but a 50% effective cost of capital has a great effect on the choice of technology in cases where labor availability is less of a constraint. A 20% effective cost of capital has very little effect on the choice of crop-production technology (Table 8). At Rigial Oubandawaki, where labor availability is a serious constraint regardless of the number of days of field work per week, increasing the effective cost of capital from 20% to 50% favors the third treatment when 5 and 7 days of field work per week are assumed but has no effect when 6 days of field work per week are assumed (Table 9). Similarly, when only 5 days per week are available for field work at Maiguéro, increasing the effective cost of capital from 20% to 50% has no effect on the allocation of fields. However, when 6 days per week are available for field work at Maiguéro, increasing the effective cost of capital from 20% to 50% reduces the proportion of fields planted to the fourth treatment from 72% to 55%. When 7 days per week are available for field work at Maiguéro, increasing the effective cost of capital from 20% to 50% reduces the proportion of fields planted to the fourth treatment from 100% to 73%.

Use of hired labor can greatly increase the proportion of fields on which the fourth treatment can be planted and weeded in a timely manner. At Maiguéro, assuming a 20% cost of capital, use of hired labor in the optimal planting and first weeding periods causes all fields to be planted to the fourth treatment (Table 10). At Rigial Oubandawaki, assuming a 20% cost of capital, use of hired labor in the optimal planting and first weeding periods increases the proportion of fields planted to the fourth treatment from 27% to 75%. A total of 10.4 person-days of labor are hired at Maiguéro, and 39.1 person-days are hired at Rigial Oubandawaki.

However, limited availability of hired labor or a high cost of capital may greatly reduce the amount of labor that can profitably be hired. It is rarely possible in the Madarounfa villages to hire labor in the first planting periods of the crop season because nearly all of the adults are

planting their own individual or collective fields. Elimination of the possibility of hiring labor in periods HI, H2 and H3 reduces the amount of labor hired to 7.9 person-days at Maiguéro and 22.7 person-days at Rigial Oubandawaki (Table 10). However, as long as the cost of capital remains at 20%, the proportion of fields planted to the fourth treatment is little affected by the elimination of hired labor during periods H1, H2 and H3. A 50% effective cost of capital limits hired labor to 2.9 person-days at Maiguéro and 11.3 person-days at Rigial Oubandawaki (Table 10). Only in the first planting period for cowpeas (H3) is it profitable at either village to hire labor when the cost of capital is 50%. Therefore, if hired labor were unavailable in this period, none would be hired in any period.

It is important to note that the cost of capital appears to influence the choice of crop technology 1) by reducing the profitability of planting and weeding the fourth treatment in periods that have substantial yield penalties and 2) by reducing the profitability of hiring labor to overcome labor-availability constraints. A review of the budgets presented in Tables 2 and 3 reveals that the fourth treatment would continue to offer the highest returns to labor and management in each village if a 50% cost of capital were added. The model results reflect this by consistently allocating most available family labor to the fourth treatment in the earliest planting and weeding periods, regardless of capital cost. However, when yield penalties for late operations and the greater labor-time requirements for the fourth treatment are considered, a 50% cost of capital makes it less profitable to plant and weed the fourth treatment in the later periods than to plant and weed other treatments.

PRODUCTION RISKS

A simple analysis of production risk indicates that the choice of crop technology may be very sensitive to risk perceptions, particularly at Rigial Oubandawaki and when a 50% cost of capital is assumed. Using the yields that provide the lowest 25% of gross revenues per hectare, and assuming 6 days of field work per week and no cost of capital, there is little change in the allocation of fields among treatments at Maiguéro, but at Rigial Oubandawaki, 45% of the fields are planted to the first treatment, and the proportions of fields planted to each of the other treatments decline (Table 11). Assuming a 50% cost of capital and a 6-day work week, the proportion of fields at Maiguéro planted to treatment 3 increases from 20%, with actual gross revenue (Table 9), to 40%, assuming the lowest 25% gross revenue (Table 11), whereas proportions planted to the second and fourth treatments decline. But at Rigial Oubandawaki, the combination of low yields and 50% cost of capital causes the first treatment of traditional practices and millet varieties to be planted exclusively.

IMPLICATIONS FOR FERTILIZER ADOPTION

The results of these various analyses may help explain much of the reluctance of farmers in the Madarounfa arrondissement of Niger to use

chemical fertilizers. Despite having many years of contact with extension agents who have promoted fertilizer use, only 12% of the farmers surveyed in these two villages used any chemical fertilizer in 1984 (on 4% of the total farm area) and only 2% of the farmers surveyed in 1985 used any chemical fertilizer (on 0.2% of the total farm area). None of the farmers surveyed in 1984 or 1985 applied fertilizer in the second half of June or in July, when urea must be applied in the fourth treatment of the INRAN on-farm trials. As in the model results, most of the farmers with whom the authors have worked seem to have little trouble planting in a timely manner, but many have trouble completing weeding operations in a timely manner. Labor constraints thus appear to limit the potential for urea applications during the optimal first weeding periods.

Hired labor, which could eliminate labor bottlenecks associated with fertilizer applications, is rarely used by the farmers observed in these villages. As demonstrated in the model results, capital costs may be limiting the use of hired labor, since credit institutions do not exist near these villages, and the effective interest rates for informal loans run as high as 100%.

However, the results of the linear-programming analyses support the adoption of the technology represented by the fourth treatment on a limited scale. Except at Rigial Oubandawaki, when 5 days of field work per week or the lowest 25% of yields are assumed, the fourth treatment is included on at least 20% of available fields in every optimal farm plan. The results consistently indicate that labor during the first periods for planting and first weeding should be allocated to the fourth treatment. If labor can be hired without having to borrow money at high rates of interest, the results indicate that it is profitable to hire labor and use it to plant more of the fourth treatment.

The results certainly support the use in economic budget analyses of an opportunity cost based on prevailing wages for the labor required for planting, replanting, first weeding and the first urea application. Moreover, the suggestion made by Perrin et al. (1976) to value labor during the busiest periods of the season at 125% of the prevailing wage is generally supported by the implicit labor values provided by the linear-programming analyses. This labor value of 750 francs CFA/day was met or exceeded by the implicit labor values for periods H3 through H4 and S3 through S4, assuming 5 or 6 days of field work per week, even when a 20% cost of capital is considered. Opportunity costs for other crop operations may be minimal but cannot be determined from this analysis because so many other agricultural and nonagricultural activities are not considered.

CONCLUSIONS

A linear-programming analysis of intercropped millet and cowpea production in the Madarounfa arrondissement of Niger demonstrates how the availability and management of family labor and hired labor may affect the choice of crop technology. Four treatments from a set of on-farm research trials are evaluated in this analysis. The four

treatments range from traditional practices and crop varieties (treatment 1) to a combination of fertilizer applications, high plant densities and improved varieties (treatment 4). Although economic budget analyses of the on-farm trial results indicate that returns to labor and management per hectare for the fourth treatment are superior to those for the other treatments, the linear-programming analysis indicates that labor availability may often limit the area on which farmers adopt this package of new crop technologies.

Limits on the proportion of time family members are willing to do field work, consideration of possibly large replanting requirements, consideration of capital costs and perceptions of substantial production risks all tend to limit the adoption of labor-intensive crop technology. Capital costs supplement the effect of limited labor availability on the choice of technology but do not act independently.

Hired labor can greatly increase the area on which labor-intensive crop technology can profitably be adopted. Hiring labor is profitable during the optimal planting and first weeding periods, provided that it is available and provided that the cost of capital is moderate.

It appears that the additional labor requirements for urea applications during the optimal periods for cowpea planting and first weeding may discourage Nigerian farmers from using fertilizers. If practices that reduce labor requirements for urea applications, cowpea planting, cowpea replanting and first weeding can be developed, these would tend to increase the use of fertilizer and increase food production. The possibility of using phosphate fertilizer, applied before the first rains, without urea fertilizer, should be investigated and has been included in INRAN's 1987 on-farm trials for intercropped millet and cowpeas.

It also appears that a lack of low-cost credit in rural areas may be limiting the use of fertilizer. A lower cost of capital would not only reduce the cost of fertilizer and seed, but also make it profitable to hire more labor in periods when family labor constraints limit fertilizer use. Development of rural credit institutions in Niger could make fertilizer more available to farmers and more profitable to use.

The package of improved crop varieties, increased plant density and fertilizer applications developed by INRAN for intercropped millet and cowpeas has shown a strong potential in on-farm trials for increasing food production. It also appears to provide attractive economic returns to labor and management. However, labor and institutional constraints in rural Niger may limit the adoption of this technology unless changes in economic conditions reduce the effect of these constraints, or until this technology can be better adapted to them.

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Table 1. Average yields per hectare for millet, cowpea grain and cowpea hay, by treatment and by village, 1985 and 1986 on-farm trials.

Item	Yield by treatment (kg/ha)			
	T1	T2	T3	T4
1985 on-farm trials:				
Maiguéro				
millet grain	284 b[1]	358 b	309 b	590 a
cowpea hay[2]	778 c	787 c	1,069 b	1,387 a
1986 on-farm trials:				
Maiguéro				
millet grain	279 bc	310 b	238 c	627 a
cowpea grain	67 c	84 c	150 b	245 a
Rigial Oubandawaki:				
millet grain	200 b	184 b	162 b	325 a
cowpea grain	113 c	140 bc	196 b	348 a

[1]Numbers within rows followed by the same letters are not significantly different at the 5% confidence level, based on Duncan's multiple range test.

[2]No cowpea grain was produced in 1985 because of late season drought, and in 1986 no cowpea hay was harvested because participating farmers were not sufficiently interested.

Table 2. Budget analysis of millet-cowpea intercrop treatments, based on prices at harvest, Maiguéro on-farm trials, 1986.

Item	Treatment (FCFA/ha)			
	T1	T2	T3	T4
Gross revenue	13,610	16,007	19,119	38,374
Variable input costs:				
cash input costs	624	1,000	2,080	10,330
opportunity cost of labor[1]	16,908	16,320	22,344	30,036
total	17,532	17,320	24,424	40,366
Returns to:				
labor and management[2]	12,986	15,007	17,039	28,044
labor per day of work[3]	461	552	458	560
management[4]	-3,922	-1,313	-5,305	-1,992

[1]Based on 600 francs CFA/person-day equivalent.
[2]Gross revenue minus cash input costs.
[3]Measured in francs CFA/person-day equivalent.
[4]Gross revenue minus total variable input costs.

Table 3. Budget analysis of millet-cowpea intercrop treatments, based on prices at harvest, Rigial Oubandawaki on-farm trials, 1986.

Item	Treatment (FCFA/ha)			
	T1	T2	T3	T4
Gross revenue	14,836	16,688	20,562	37,626
Variable input costs:				
cash input costs	624	1,000	2,080	10,330
opportunity cost of labor[1]	17,322	18,072	23,988	31,392
total	17,946	19,072	26,068	41,722
Returns to:				
labor and management[2]	14,212	15,688	18,482	27,296
labor per day of work[3]	492	521	462	522
management[4]	-3,110	-2,384	-5,506	-4,096

[1]Based on 600 francs CFA/person-day equivalent.
[2]Gross revenue minus cash input costs.
[3]Measured in francs CFA/person-day equivalent.
[4]Gross revenue minus total variable input costs.

Table 4. Proportion of total farm area planted to each treatment and resulting net cash revenue, assuming 5, 6 and 7 days of field work and no cost of capital, by village, on-farm trials, 1986.

Village and days of field work	Proportion of total total farm area (%)			Net cash revenue (FCFA)
	T2	T3	T4	
Maiguéro:				
5 days	61.3	--	38.7	15,228
6 days[1]	25.5	--	74.5	25,298
7 days	--	--	100.0	32,912
Rigial Oubandawaki:				
5 days	94.7	--	5.3	13,289
6 days[1]	63.0	8.9	27.2	32,658
7 days	28.4	29.5	42.2	49,341

[1]Initial model assumptions.

Table 5. Allocation of labor time among treatments and crop operations, by time period and by village, assuming 6 days of field labor per week and no cost of capital, on-farm trials, 1986.

Village and time period	Person-day	Operation and treatment	Person-day	Operation and treatment	Person-day	Operation and treatment
Maiguéro:						
H1 (humid)	5.33	plant T4 millet	1.16	plant T2 millet		
H2 (humid)	1.57	plant T4 millet	0.53	replant T4 millet	0.12	replant T2 millet
H3 (humid)	5.34	plant T4 cowpea	0.98	plant T2 cowpea	0.16	replant T4 millet
S3 (dry)	9.71	weed T4				
H4 (humid)	4.32	plant T4 cowpea	1.49	apply T4 urea	0.05	plant T2 cowpea
	0.53	replant T4 cowpea	0.10	replant T2 cowpea		
S4 (dry)	9.71	weed T4				
H5 (humid)	4.08	weed T4	1.49	apply T4 urea	0.47	plant T4 cowpea
	0.43	replant T4 cowpea				
S5 (dry)	9.71	weed T2				
H6 (humid)	5.31	weed T4	0.63	apply T4 urea	0.50	weed T2
	0.05	replant T4 cowpea				
S6 (dry)	9.71	weed T4				
Rigial Oubandawaki:						
H1 (humid)	6.10	plant T2 millet	5.28	plant T4 millet		
H2 (humid)	1.69	plant T3 millet	0.61	replant T2 millet	0.53	replant T4 millet
H3 (humid)	7.72	plant T4 cowpea	3.47	plant T2 cowpea	0.17	replant T3 millet
S3 (dry)	17.12	weed T4				
H4 (humid)	5.65	weed T4	2.62	apply T4 urea	1.94	plant T2 cowpea
S4 (dry)	10.40	weed T2	6.72	weed T4		
H5 (humid)	6.94	weed T2	2.33	plant T3 cowpea	1.89	apply T4 urea
	0.19	replant T2 cowpea				
S5 (dry)	17.12	weed T2				
H6 (humid)	11.13	weed T2	0.23	replant T3 cowpea		
S6 (dry)	8.91	weed T3	8.21	weed T2		

Table 6. Implicit labor values (shadow prices) by period and by village, for 5, 6 and 7 days of field work per week and no cost of capital, on-farm trials, 1986.

Village and time period	Implicit labor values (FCFA/dry)		
	5 days	6 days	7 days
Maiguéro:			
H1 (humid)	0	826	818
H2 (humid)	0	0	0
H3 (humid)	1,791	1,661	1,096
S3 (dry)	1,475	1,221	588
H4 (humid)	1,465	1,258	642
S4 (dry)	1,327	1,085	451
H5 (humid)	1,219	929	323
S5 (dry)	1,138	831	194
H6 (humid)	1,044	741	32
S6 (dry)	968	706	0
Rigial Oubandawaki:			
H1 (humid)	0	251	190
H2 (humid)	0	0	0
H3 (humid)	1,750	1,951	1,830
S3 (dry)	1,687	1,269	1,146
H4 (humid)	1,605	1,288	1,171
S4 (dry)	1,543	1,122	1,005
H5 (humid)	1,426	1,005	843
S5 (dry)	1,339	917	696
H6 (humid)	1,230	810	589
S6 (dry)	1,134	720	568

Table 7. Proportion of total farm area planted to each treatment, by village, and resulting net cash revenue, assuming 6 days of field work per week, three replanting rates and no cost of capital, on-farm trials, 1986.

Village and replanting rate	Proportion of total total farm area (%) T2	T3	T4	Net cash revenue (FCFA)
Maiguéro:				
10% replanting[1]	25.5	--	74.5	25,298
20% replanting	30.4	--	69.6	22,882
30% replanting	36.2	--	63.8	21,300
Rigial Oubandawaki:				
10% replanting[1]	63.9	8.9	27.2	39,410
20% replanting	67.2	7.2	25.6	30,615
30% replanting	70.9	5.3	23.8	28,264

[1]Initial model assumptions.

Table 8. Proportion of total farm area planted to each treatment, by village, and resulting net cash revenue, assuming 5, 6 and 7 days of field work and a 20% cost of capital, on-farm trials, 1986.

Village and days of field work	Proportion of total total farm area (%) T2	T3	T4	Net cash revenue (FCFA)
Maiguéro:				
5 days	65.0	--	35.0	11,848
6 days	28.1	--	71.9	19,326
7 days	--	--	100.0	25,038
Rigial Oubandawaki:				
5 days	94.7	--	5.3	17,902
6 days	59.6	19.0	21.4	34,350
7 days	27.3	32.0	40.7	47,914

Table 9. Proportion of total farm area planted to each treatment, by village, and resulting net cash revenue, assuming 5, 6 and 7 days of field work and a 50% cost of capital, on-farm trials, 1986.

Village and days of field work	Proportion of total total farm area (%) T2	T3	T4	Net cash revenue (FCFA)
Maiguéro:				
5 days	65.0	--	35.0	6,872
6 days	24.3	20.3	55.4	10,455
7 days	--	27.4	72.6	13,454
Rigial Oubandawaki:				
5 days	90.6	9.4	--	14,204
6 days	59.6	19.0	21.4	26.336
7 days	20.5	47.8	31.7	35,783

Table 10. Labor hired by period, proportion of total farm area planted to each treatment, by village, and resulting net cash revenue, assuming 6 days of field work per week and two costs of capital, on-farm trials, 1986.

Village and days of field work	Labor hired by period (person-day)	Proportion of total total farm area (%) T2	T3	T4	Net cash revenue (FCFA)
Maiguéro:					
20% cost of capital, hiring in all periods	2.77 in H1 7.64 in H3	--	--	100.0	23,801
20% cost of capital, hiring after H3	4.25 in S3 3.67 in H4	--	--	100.0	21,136
50% cost of capital, hiring in all periods[1]	2.89 in H3	13.7	23.0	63.3	11,518
Rigial Oubandawaki:					
20% cost of capital, hiring in all periods	3.20 in H1 28.53 in H3 0.34 in S3 7.29 in H4	--	25.1	74.9	42,158
20% cost of capital, hiring after H3	10.05 in S3 5.83 in H4 6.86 in S4	--	25.3	74.7	34,640
50% cost of capital, hiring in all periods[1]	11.35 in H3	41.2	20.5	38.3	20.099

[1]If hired labor is available only after H3, none is hired.

Table 11. Area planted to each treatment and net cash revenue for yields providing the lowest 25% of gross revenue, assuming 6 days of field work per week and two costs of capital, by village, on-farm trials, 1986.

Village and cost of capital	Proportion of total farm area (%)				Net cash revenue (FCFA)
	T1	T2	T3	T4	
Maiguéro:					
no cost of capital	--	25.8	--	74.2	-9,005
50% cost of capital	--	16.0	39.6	44.3	-21,547
Rigial Oubandawaki:					
no cost of capital	44.7	24.3	6.9	23.8	-34,833
50% cost of capital	100.0	--	--	--	-37,247

APPENDIX A
ON-FARM RESEARCH TRIALS

Table A-1. Treatments for the 1986 intercropped millet-cowpea on-farm trials.

Variable	T1	T2	T3	T4
Variety:				
cowpea	TN 5-78	TN 5-78	TN 5-78	TN 5-78
millet	traditional	CIVT	CIVT	CIVT
Plant spacing	traditional	traditional	two rows of cowpeas spaced 75 cm apart between two rows of millet, spaced 150 cm apart	
Plant density:				
cowpea	traditional	traditional	18,000/ha	18,000/ha
millet	traditional	traditional	9,000/ha	9,000/ha
Fertilizer:				
18% P_2O_5	none	none	none	100 kg/ha[1]
42% N at:				
tillering	none	none	none	25 kg/ha[2]
heading	none	none	none	25 kg/ha[2]

[1]Broadcast and incorporated before planting millet.
[2]Applied in shallow holes beside pockets of millet.

Table A-2. Average labor times per hectare for specified operations, by treatment, on-farm trials, Madarounfa,[1] 1986.

Operation	Labor times by treatment (PDE/ha)[2]			
	T1	T2	T3	T4
Application of phosphate	0.00	0.00	0.00	2.58
Planting of millet3	1.22	1.18	2.36	2.41
Planting of cowpeas3	0.98	1.05	3.25	3.54
First weeding	11.32	10.44	12.44	13.46
First urea application	0.00	0.00	0.00	2.06
Second weeding	7.78	7.76	8.40	8.48
Second urea application	0.00	0.00	0.00	1.66

[1]From observations of 17 farmers in Maiguéro, Rigial Oubandawaki, and Kandamao.

[2]One person-day equivalent (PDE) equals 8 hours. For all operations except planting, observed times for women are multiplied by 0.6, and times for adolescents are multiplied by 0.5.

[3]Does not include replanting time.

Table A-3. Millet-yield regression results, Maiguéro and Rigial Oubandawaki, on-farm trials, 1986.

Explanation	Constant	Rigial dummy	P_2O_5	Planting date	Days before weeding[1]
Treatment 1:[2]					
coefficient	2,317.38	-249.04	35.79	-10.92	-7.27
std. error of coeff.	102.10	42.19	14.01	2.22	3.64
R^2 = .60; d.f. = 43					
Treatment 2:[2]					
coefficient	1,703.35	-242.34	55.78	-8.06	-4.39
std. error of coeff.	121.43	55.95	17.23	2.81	4.22
R^2 = .42; d.f. = 41					
Treatment 3:[2]					
coefficient	1,810.10	-185.77	36.53	-9.03	-3.17
std. error of coeff.	84.00	39.77	12.03	1.88	2.80
R^2 = .49; d.f. = 40					
Treatment 4:					
coefficient	2,135.64	-429.68	--	-7.97	-4.47
std. error of coeff.	142.62	48.23		2.53	3.72
R^2 = .60; d.f. = 54					

[1]Days before weeding defined as first weeding date minus first millet planting date.

[2]For cases where days before weeding are greater than 23.

Table A.4. Cowpea-yield regression results, Maiguéro and Rigial Oubandawaki, on-farm trials, 1986.

Explanation	Constant	Rigial dummy	P2O5	T2 dummy	T5 dummy	Planting date	Days before weeding[1]
Treatments 1 and 2:							
coefficient	404.06	--	6.76	18.22	--	-1.56	-1.97
std. error of coeff.	58.67		5.00	10.91		0.75	1.12
R^2 = .19; d.f. = 111							
Treatment 3:[2]							
coefficient	219.66	48.97	24.23	--	--	--	-5.75
std. error of coeff.	79.81	27.59	11.31				3.78
R^2 = .20; d.f. = 38							
Treatments 4 and 5:[3]							
coefficient	1,150.53	--	--	--	81.97	-3.77	-6.61
std. errof of coeff.	146.71				30.27	1.82	4.16
R^2 = .19; d.f. = 90							

[1]Days before weeding defined as first weeding date minus first cowpea planting date.

[2]For cases where days before weeding are greater than 20 and less than 36.

[3]For cases where days before weeding are greater than 20 and less than 37.

Treatment 5 is identical to treatment 4 except that insecticide was applied to treatment 5.

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FSR/E, DEVELOPMENT INDICATORS AND FOOD SELF-SUFFICIENCY AT THE HOUSEHOLD LEVEL IN MALAWI

Anita Spring[1]

INTRODUCTION

The terms "farming systems research and extension" (FSR/E) and "gender issues" are like codes (Poats et al., 1987). Each is shorthand for an extensive interdisciplinary field that links technical, economic and sociological studies. A "farming system" is often descriptive of the crop and animal enterprises in an area in relation to the marketplace. FSR/E is both a methodology and a perspective that treats the farm as a system with a focus on smallholders who have few resources and who generally use family labor. These smallholders attempt to minimize risk, are involved in multifaceted activities (sometimes including off-farm activities) and are oriented both to the market and to nonmarket economies.

The household is usually taken as the unit of any approach that deals with the farming system because it is concerned with production and consumption. The household is seen as the bounded unit in which external factors that are outside the control of the household decision-maker(s) may be distinguished (Guyer, 1986). The standard approach has been to examine the household as an aggregate unit rather than to look at its constituent parts. Usually this has meant that male household heads have been selected to "represent" the household. However, researchers who have studied the dynamics of African households point to problems with the household as the unit because of the semiautonomous nature of its members where "men and women...separately control productive resources, make independent decisions, manage personal incomes, assume different responsibilities, and favor different investments" (Guyer, 1986). Many writers recognize the different resource bases and different responsibilities of individuals and the separate incomes and expenditures of men and women and of husbands and wives within the household (Gladwin et al., 1984; Guyer, 1984; McMillan, 1986; Rogers, 1980; Spring, 1986a and 1986b). These authors state that farming households in Africa have overlapping but semiautonomous units, and that women are not simply embedded within a household but make food production and distribution decisions. Male and female household heads have been compared by some authors (Due and White, 1986; Spring et al., 1983; Spring, 1984; Hansen, 1987), although Peters remarks that the attention to female heads may "divert attention away from the role of...women as farming wives, sisters and daughters" (Peters, 1986).

The focus on gender issues in development started with Boserup (1970), who argued that economic and agricultural innovation and development often undermine women's status. Excluding women in planned and unplanned agricultural interventions was examined in the 1970s by a series of case studies that documented women's participation in agriculture and the neglect of women by government and donor

[1]University of Florida, Gainesville, FL 32611, U.S.A.

organizations. These case studies often focused predominantly on women and mostly considered the sexual division of labor. Gender analysis in the 1980s, by contrast, has tended to focus on the importance of gender in research and extension and has attempted to link development project goals with gender. Questions addressed are what happens when gender is either left out or included in development efforts, and what are the differences in the client population in terms of planned and unplanned interventions (Overholt et al., 1985). The FSR/E emphasis on delineating client population and reaching smallholders, particularly low-resource agriculturalists, has helped illuminate women's roles in agricultural development because so many women fall into the low-resource category.

GENDER DIFFERENCES AND FARMING PRACTICES

This paper is a case study of the differences in farming practices of smallholders in relation to development activities and services. To ascertain gender similarities and differences, the following will be considered:

- The differences in farming practices between two types of households: male-headed households (MHHs) and female-headed households (FHHs). These two types of households are taken as analytical constructs, although it would also be possible to consider them as two-adult and one-adult households or to distinguish the female-headed households in terms of married and unmarried women.

- The farming practices of men and women in the same households, that is, husbands and wives in the male-headed households.

- The effects of rural-development services on the farming systems of both male and female smallholders. In particular, commonalities and constraints of smallholders are identified in order to differentiate them from problems that are related to gender and those generic to smallholders.

THE PROJECT SETTING

The research was part of the Women in Agricultural Development Project in Malawi (WIADP), which was funded by the U.S. Agency for International Development (USAID) Office of Women in Development and functioned as a nationwide project through Malawi's Ministry of Agriculture. The project had research, training and policy components that accomplished the following (Spring, 1985, 1986a, 1986b, 1988a, 1988b):

- the collection of data on female and male smallholders in terms of their farming practices, development project services addressed to them and output and results in terms of farming (Spring et al., 1983; Spring, 1984; Spring 1986a);

- the establishment of mechanisms to disaggregate data by gender in collection, analysis and monitoring phases (Spring, 1985);

- the execution of a series of FSR/E trials (Spring, 1986a, 1987, 1988a);

- leadership training and retraining of extension staff, including the legitimization of the male extensionists to work with women farmers (MOA, 1983; Spring 1983):

- work with policy-makers and planners to target in national development plans (Spring, 1983; Spring et al., 1983).

The data on farming practices and project services that are the focus of this analysis come from the Lilongwe Rural Development Project (LRDP), funded since 1968 by the World Bank. As an integrated rural development project, the LRDP includes extension services, infrastructure, political development, crop and livestock development and the monitoring of these activities. Farmers in the area grow maize, tobacco, groundnuts and some beans and sweet potatoes under rainfed conditions, often in pure stands. Only 11% own cattle; some own goats and chickens. Size of land holding averages about 1% ha. About one-fifth, or 20%, of the households are headed by women. (A more detailed description of the project may be found in Kydd, 1982; Lele, 1975; Spring, 1984).

The information that is analyzed here comes from two formal diagnostic surveys. One, called the National Sample Survey of Agriculture (NSSA), was funded by the World Bank and carried out by the Ministry of Agriculture; the second is a survey of development indicators carried out by the WIADP and the farming-systems-analysis section of another USAID project. According to the literature, a number of authors have tried to identify indicators of development (Castro et al., 1981; Kydd, 1982). These indicators include such aspects as:

- demography -- household size and composition, education, migration and urban and international experiences;

- land —- control, types, tenure and acquisition;

- productive resources —- capital equipment, farm equipment, condition of the main house;

- cropping patterns —- crops planted, use of inputs, experience cultivating improved varieties and farming practices;

- yields;

- local people's perceptions of development and their knowledge of development services, including their perceptions of change as a result of the project and their adoption of innovation;

- contact with extension staff;

– wealth and income of the farmers.

The WIADP survey attempted to include these indicators in the design of its survey instruments.

DISCUSSION OF DEVELOPMENT INDICATORS AND FINDINGS

Because of space limitations, the characteristics of farmers in the LRDP are presented here in terms of the indicator and the finding. The statistical support material may be found in Spring, 1984 and 1988a.

Demography

Figure 1 summarizes the demographic features of the households. One-fifth of the households are headed by women; of these 39% are married, but their husbands are away from the family farm. The sex of household head may change over time because of male migration, divorce and remarriage and death. The WIADP queried the stability of the FHHs over time. At first glance, the numbers appear stable since the data show that there were 58 of them in 1980/1989 and 61 in 1981/1982. But on closer examination, 12% of the 58 FHHs in 1980/1981 became male-headed households (MHHs) in 1981/1982. Similarly, of the 61 households headed by women in 1981/1981, 16 were headed by men during the previous year. Therefore, in only 1 year, one-sixth of the households changed. (It is not possible to know what the changes are over a longer period of time with the data collected – see Hansen, 1987, for a more detailed explanation.).

Although families average 5.3 persons, those headed by women contain 1 less person. An examination of age, sex and relationship to the household head shows that the difference is primarily that of an adult male (husband), since the average number of women and children does not differ between the two types of households. Women in both types of households have similar reproductive experiences (an average of 6.9 pregnancies and 4 living children). Parents have less education than do their children; children in FHHs and girls in both types of households have less education than do the boys. Women have less education, and most are illiterate compared with men whose education, literacy and migration experiences are greater.

Land

The majority of gardens cultivated are rainfed; streamside gardens are at a premium; little land is under fallow. Land for gardens may be acquired through inheritance or purchase, as a gift or loan, or by clearing. Each sex tends to obtain land from a relative of the same sex, mostly through gifts or inheritance. The households headed by women have fewer gardens because of the way land is acquired. Since only one-third of the females heading households are married, the remainder does not have the option to acquire land through the husband's relatives. Figure 2 shows that the average land holding size for MHHs is 1.83 ha; for FHHs it is 1.27 ha or 1.53 ha, depending on which sample is used. The majority of the farmers have between 1 ha and 2.5 ha, but

22% of the MHHs have more than 2.5 ha compared with only 2% of the FHHs. One half of the FHHs cultivate less than 1 ha, compared to only 18% of the MHHs. There are no differences between households in terms of the average hectarages of each crop grown.

Cropping Pattern

An examination of the cropping patterns (Fig. 3) shows that all households grow local maize and then add other food or cash crops. The most common second crop is groundnuts, followed by hybrid maize and tobacco. Innovative crops were introduced into the farming system by the LRDP and include tobacco, hybrid maize and synthetic maize. Although the data are divided according to cropping patterns into a two-fold scheme (innovative and noninnovative), 22 patterns are identifiable (Hansen and Ndengu, 1983). The noninnovative, or traditional, cropping patterns include combinations such as local maize, groundnuts, sweet potatoes, green beans and fallow. The most frequent pattern consists of local maize and groundnuts; more than one-half of the FHHs and 38% of the MHHs exhibit these patterns. The houses headed by women grow cash crops as well as food crops, although fewer of the FHHs than the MHHs grow tobacco and hybrid maize. Tobacco in particular is thought to be a "man's crop," and so the technical aid goes to the men. It is, therefore, intriguing that women manage to grow it at all, but almost one-fifth of the FHHs do so. Farmers growing innovative crops have twice the amount of land (2.41 ha) as those with traditional patterns (1.28 ha). One conclusion is that the availability of land is the most significant variable in innovative cropping patterns, although contact with extension services is also important.

Productive Resources

Most households rely on the basic agricultural tool, the hoe, and make few improvements to their houses. Consumer goods such as tables, lamps, chairs, radios and bicycles are not owned by most. Male-headed households have more items than do FHHs, and the innovative farmers have more wealth items, including farm equipment, than do the noninnovative farmers (Fig. 4). Few households have improved houses with baked bricks or cement floors, but more MHHs have glass windows than do FHHs. A main housing improvement that requires labor rather than cash is the latrine. Female heads of households have fewer of these, probably because they lack male labor to build them.

Labor

Figure 5 sums up the information concerning labor, showing that MHHs have more units than do the FHHs, and the innovative farmers have more than do the noninnovative farmers. The WIADP used two different methods to cal-culate the labor units available in a household. The method common in the literature (called "standard" here) counts male labor as 1 and female labor as 0.67 for comparable activities. A second method, devised by the WIADP, is more "equalitarian" and counts men and women's labor as equal but distinguishes people by age. The analysis shows that the male heads have more labor units than do the female heads in both cases. The results of these labor configurations and yields are

reflected in the consumption units and volume of stored maize. Innovative farmers have both more labor and land, which are directly related to the household's ability to feed more people. However, the increased labor available in the MHHs affects total production. This is because additional land is cultivated, not because higher yields per area are obtained. The lack of significant differences in yields for both local and hybrid maize in the two types of households indicates that the labor tasks performed by the women are those most affecting efficiency of output.

Consumption

Innovative households have more stored maize and more consumption units (Fig. 6). Households that produce more can allow more people to stay with them. One farmer defined "development" for the WIADP staff as "when you don't have to send your children away because you can take care of them (feed and clothe them) properly."

There are also correlations between the amount of land, consumption units and stored maize. These correlations illustrate again the importance of landholding size. In addition, the correlation between innovative cropping pattern and consumption units demonstrates that innovative farmers have more land and store more maize. This is especially true for the FHHs growing innovative crops where the mean volume is 4.9 m^3 compared to 1.1 m^3 for those female heads growing noninnovative crops.

Cultural Practices and Knowledge of Improved Practices

Farmers' cultural practices such as time of planting, plant spacing and populations, weeding and fertilizer usage were examined, as well as their use of improved technologies and knowledge of improved farming practices. Male and female farmers are alike in terms of when they prepare their land and when they plant their crops unless they have been contacted by extension and have adopted recommended practices. Extension recommendations stress early land preparation, early planting (including dry planting) and specific plant populations in terms of seeds per station and spacing between stations and ridges. Because extensionists tend to focus on men, more men than women know and use the recommendations.

Women, whether they are in MHHs or are farm managers themselves, know less than men about types of fertilizers and applications, credit and its procedures, time of planting, spacing, plant populations, time of weeding and disease and pest management. They also have less access to improved seed and technologies (Fig. 7). For example, there is a difference between household types in terms of knowledge of fertilizer usage. Fertilizers need to be applied at planting time and again when the plants are small, but most farmers say fertilizers should be applied later in the growth cycle. The men correctly apply the fertilizer in greater frequencies than do the female heads (66% versus 47% for 1980 and 42% versus 11% for 1981). The incorrect information correlates with both stated and observed application. It is, therefore, not surprising that yields are low because maize plants cannot absorb the nutrients

late in the growth cycle. The number of farmers who apply fertilizer too late in the growing cycle is large and constitutes a major constraint to improving yields.

Extension

The majority of people receive no extension contacts. Of those who do, most see the extension worker at group meetings and personal visits, but contact is always much higher for men than for women (Fig. 8). Men tend to be the members in farmers' clubs and, therefore, eligible for credit; fewer wives are members, but even they are more likely to be members than are the female household heads.

Yield

Differences in yields probably have less to do with real differences in farming skills (because both men and women seem equal in this respect) than with growing innovative crops, having increased hectarage and having access to inputs and extension information. The data demonstrate that women produce yields comparable to men's with less available labor and with fewer inputs (Fig. 9). Local maize yields are significantly lower (MHHs = 1,419 hg/ha; FHHs - 1,252 kg/ha) than the hybrid maize yields (MHHs - 3,676 kg/ha; FHHs - 3,921 kg/ha). Only 25% of the local maize plots are fertilized, and only one-half of these plots show the increased yields as a result of fertilizer usage. Hybrid maize yields are also undifferentiated by sex of farmers although many more of the MHHs than FHHs grow the crop; virtually all farmers who grow the crop fertilize it. More of the female heads than the male heads continue to apply their fertilizers too late because they have received no information on correct usage, demonstrating that both men and women need more information to prevent late fertilizer application. The differences between the two types of households become apparent when total production that accounts for size of landholding is calculated. There are no differences in local maize, but with hybrid maize, the MHHs with their greater hectarage have twice the production of the FHHs (4,609 kg versus 2,704 kg). Because the female heads have less land and labor than do the male heads, they are not able to grow as much food and(or) cash-producing crops, and their total yields are lower.

Change and Development

The LRDP began in 1968, although not all farmers in the various surveys have lived in the project area or have had infrastructural and other resources available to them for the entire length of time. Farmers were asked how they felt about various aspects of their agricultural production such as food self-sufficiency and use of infrastructure and services over the years. Farmers see hybrid maize and credit as the main services that the LDRP has brought to them (Fig. 10). They note marketing facilities as a main result of the LRDP, but more male than female house-hold heads say the markets have helped them. Only 40% of all households believe there is more food, and 54% say they have more income as a result of the project. Another 40% believe there is less food, and 44% say they have less income since LRDP came into existence.

The FHHs in particular feel less impact of the LRDP in terms of inputs, marketing and credit.

Income

All households require cash income, and most obtain their money from agricultural sources (Fig. 11). Once again, differences in crops are apparent between the two types of households. Men gain cash from tobacco and hybrid maize, commodities that tend to generate substantial income; women rely on groundnut sales that provide more modest returns. The male household heads also gain income from produce from streamside gardens. In terms of generation of nonagricultural income, women rely on beer brewing while men are more likely to find off-farm employment that is higher paying.

CONCLUSION

Because of increasing male mobility, the basic smallholder farm unit is the woman and children (although children may be in school and unavailable for farm work). Households that have the husband present for most of the year have increased land, labor, access to resources and extension services compared with households without adult males. When labor and other resources are constrained, compensations in the farming system must be made. The female-headed household simplifies the farming system and generally grows fewer crops, especially innovative crops such as tobacco and hybrid maize. As a result, there may be a return to (or a continuation of) a more traditional cropping system that generates little or no income as access to improved seed, fertilizer and advice is reduced.

Women work, as farmers in households headed by men or by themselves. They actively manage the farm if husbands are not there or if they have no husbands. Since men prefer off-farm employment, the farming responsibil-ities fall to their wives. Some of the men do not return or return sporadically; others use their off-farm cash income to develop their farms. Marriages may be strained by male mobility, and unions in this area are capable of dissolving easily. Women may be married one farming season and separated, divorced or widowed the next. Men have the option of having more than one wife and household, thereby being only a part-time participant in each household. Women, therefore, may find themselves managing the farm alone; they are farmers all their lives.

Yet, there is diversity within the MHHs and the FHHs. Some of the FHHs are impoverished and have few resources and less possibility of educating their children. Some female heads of households cultivate large hectarages with improved technologies and use their remuneration for improved housing, consumer goods and children's education. The continuum of the MHHs likewise ranges from impoverished to affluent, but there are more MHHs than FHHs in the affluent category. Note that an initial examination of the data concerning the two household types shows that the MHHs cultivate more land than the FHHs and that more of the MHHs cultivate hybrid maize or tobacco. As a result, some researchers

and extensionists have argued that the MHHs are therefore "worthier" of praise, attention, credit and so forth than are the FHHs. Some of these "experts" also concluded that men are better farmers than are women because average holding size or (total) yields are higher for them. However, access to inputs, technical advice and resources need to be considered as well. The MHHs' increased ability to grow innovative crops allows them to take advantage of extension recommendations and new technologies, while contact with extension increases their ability to use these new technologies.

Two sets of FSR/E on-farm, farmer-managed trials in Malawi confirmed some of these points. The first set was carried out in the LRDP and focused on soybeans; women farmers participated exclusively (Spring, 1986). FSR/E methodologies (surveys and testing of technologies) were used to prove that women were cultivators of field crops in their own right, counteracting the notion that women were "farmers' wives" or only occasional farmers. The trials showed that some problems, such as lack of agronomic training and adequate amounts of seed to plant, were specific to women. By contrast, a problem that was generic to all smallholders (the type and preparation of rhizobium inoculant for nodulation of the plant) was identified. Then trials were designed with the women as cooperators, and they were able to carry out the trials with precision. The trials demonstrated that differences in results related to training, not to gender.

Similarly, in another set of trials elsewhere in Malawi, the characteristics of the farmers selected by extension personnel as cooperators tended to differ by gender (Spring, 1987 and 1988a). The men selected were mostly younger, high-resource farmers with adequate family labor and extension training; as cattle owners their lands were fertilized with manure. The women selected were mostly older, female heads of households who were low-resource farmers with no other family labor, extension contacts or cattle. The results of these maize trials have been subjected to a modified stability analysis (Hildebrand and Poey, 1985; Hansen, 1986) showing that in the good environments of the high-resource farmers, the improved cultivar did better, while in the poor environments of the low-resource farmers, the unimproved cultivar was superior. Fertilizer increased yields in both cases, but was much more significant in the good environments and much more costly (in terms of potential failure) in the poor environments. The analysis by gender demonstrated that most, but not all, of the women selected tended to fall into the poor-environment situation because of land shortages, lack of extension information and lack of family labor (Spring, 1987). In this case, lack of access to land and capital as well as differences in training and extension contacts separated male and female farmers. New strategies, including credit and technical packages, leadership training and extension contacts were needed to increase the food self-sufficiency of these women and were subsequently carried out.

To conclude, the data from both the National Sample Survey of Agriculture and the LRDP survey, as well as from the field trials, show that men and women do not differ in basic farming skills and practices but that differences in resources, exposure to new technologies and access to services have consequences for the outcome of production and

the quality of life. By examining the data at the household level rather than looking only at project production yields or numbers of participants in a program, it is possible to discern the characteristics of smallholders and the impact of the exogenous factors on the farming system. By disaggregating the household into type and into the adult individual members (male and female), it is possible to understand the level of resources and knowledge, the access to development project services and the results of the farming system on the food supply and household food self-sufficiency.

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Indicator		Finding
Sex of head of household	-	MHHs 80%, FHHs 20%’
	-	FHHs: 39% are married, 31% are widows
	-	16% of FHHs changed to MHHs and 12% of MHHs changed to FHHs in 1 year
Household size	-	Average = 5.3 persons
	-	MHHs = 5.5 persons
	-	FHHs = 4.2 persons – 1 less person
Natality	-	No differences in number of children for FHHs and MHHs
		- 6.9 pregnancies
		- 4.0 children
Education:		
Adult	-	MHHS > wives > FHHs
Children	-	Boys > girls
	-	Children in MHHs > children in FHHs

Fig. 1. Demographic and education features of households as determined by data analyzed for the Lilongwe Rural Development Project (LRDP).

Indicator	Finding
Acquisition	Much acquired from relative of same sex through inheritance and gifts
Length of time held	No difference between MHHs and FHHs
Garden types	- Seepage: MHHs > FHHs - Total: MHHs > FHHs
Range	FHHs have a smaller minimum (0.18 ha) and a larger maximum (5.6 ha) than MHHs (0.4 ha and 4.84 ha). However, only 1 FHH has more than 2.5 ha. Standard deviation is smaller for MHHs (0.9) than for FHHs (1.2)
Mean	MHHs > FHHs, but the means are closer together as the number of FHHs in the sample increases MHHs / FHHs Sample 1: 1.83 / 1.53 (n.s.) Sample 2: 1.83 / 1.27 (sigT(99) = 2.58 p < 0.1)
Distribution of landholdings	MHHs tend to have larger land holdings (1.0 ha to 2.5 ha) while FHHs tend to have smaller holdings (less than 1 ha). Most farmers, however, are in the middle range MHHs / FHHs < 1 ha: 18% / 50% 1 ha-2.5 ha: 60% / 48% > 2.5 ha: 22% / 2%

Fig. 2. Land: method of acquisition, types and holding size.

Indicator	Finding
Innovative and noninnovative crops (Innovative crops are hybrid/ synthetic maize, and tobacco)	Both MHHs and FHHs grow food and cash crops More MHHs grow tobacco, hybrid maize, sweet potatoes, green beans and mixed beans No difference in the number of growers for local maize, groundnuts, synthetic maize, ground beans MHHs – 22 patterns FHHs – 11 patterns Most frequent patterns:

	FHHs	MHHs
Local maize and and groundnuts	53%	34%
Local maize, groundnuts, tobacco*	10%	14%
Local maize	12%	8%
Local maize groundnuts, hybrid maize*	3%	6%
Other 18 patterns (includes *)	18%	38%
	100%	100%

Cropping patterns and wealth	Innovative farmers own more wealth items than do noninnovators
Cropping patterns and hectarage	Farmers growing innovative crops have more total land than do noninnovators (2.41 ha compared to 1.28 ha)
Hectarage and type of crop	No diference between household types in the mean hectarages for crops

Indicator	Finding
Farm equipment	- No difference in basic implements (hoe, ridgers, plough) - MHHs have more water cans, ox carts
Housing	MHHs have more glass windows, latrines
Consumer goods	MHHs have more bicycles, tables, lamps, chairs, radios
Hectarage	Farmers with more land own more wealth items $r = .31$, $p < 0.1$
Cropping pattern (innovators versus noninnovators)	Innovative farmers have more items than do noninnovative farmers $r = .32$, $p > .01$

Fig. 4. Ownership of wealth items (farm equipment, housing, consumer goods).

Indicator	Finding		
	Mean: MHHs > FHHs		
		MHHs	FHHs
Size of labor force	"Standard"		
	mean	2.95	2.35
	minimum	1.67	0.67
	maximum	6.8	6.8
	"Equalitarian"		
	mean	3.34	2.76
	minimum	1.6	0.80
	maximum	7.3	7.5
Cropping patterns	Innovative farmers (MHHs and FHHs) have more labor units than do noninnovative farmers (3.4 units versus 2.9 units)		
	$f(1) = 4.6,\ p < .03$		

Fig. 5. Size of labor force and cropping patterns.

Indicator	Finding
Units and cropping pattern	Households growing innovative crops have more consumption units
Units and hectarage	Households with more consumption units have greater hectarage ($r = 0.26$, $p < .001$)
Stored maize per consumption unit	Household growing innovative crops have more stored maize per consumptions unit (significant for all households and MHHs, but not for FHHs) 1.8 versus 1.1, $p < .02$
Stored maize per consumption unit and hectarage	Households with more stored maize per consumption unit have more hectarage ($r = 0.34$, $p < .001$)
Total volume stored maize	- Higher mean for innovative households (1.84) than for noninnovative households (1.13) - Innovative FHHs have a much higher mean (2.9) than do noninnovative FHHs (1.1)

Fig. 6. Consumption units.

Indicator	Finding
Cultural practices	- No difference in time of land preparation, planting or weeding - No difference in plant populations
Knowledge of correct cultural practices	MHHs > wives > FHHs
Use of fertilizer	MHHs slightly more in “good” years and much more in scarce years
Knowledge of types and prices of fertilizers	MHHs > FHHs > wives
Knowledge of correct usage	Few farmers know correct usage Wives > MHHs > FHHs
Application of fertilizer	More MHHs than FHHs apply fertilizer correctly, but many farmers apply incorrectly (method and timing)

Fig. 7. Cultural practices and knowledge of improved practices for MHHs and FHHs.

Indicator	Finding
Amount of advice	For those receiving advice: - Majority receive none - Men receive twice as much as women - MHHs (45%), wives (26%), FHHs (25%)
Source of advice	For these receiving advice: - Group meetings are main method MHHs (66%), FHHs (49%), wives (44%) - Extension worker visits are second method MHHs (41%), wives (28%), FHHs (23%)
Club membership	MHHs > wives > FHHs

Fig. 8. Households receiving advice from extension and method of obtaining that advice.

Indicator		Finding
Local Maize		
Mean yield	-	No significant differences between MHHs and FHHs (1,419 kg/ha and 1,252 kg/ha)
Fertilizer use	-	25% of farmers use fertilizer (no difference between MHHs and FHHs, but only one-half obtained higher yields.
Hybrid Maize		
	-	More MHHs than FHHs grow the crop
Mean yield	-	No significant differences between MHHs and FHHs (3,676 kg/ha and 3,921 kg/ha)
Fertilizer use	-	Almost 100% (no differences between MHHs and FHHs)
Hectarage	-	MHHs with higher yields of local maize have a greater hectarage r - .26, p < .01
	-	No correlations between yield of hybrid maize and hectarage

Fig. 9. Yields produced by MHHs and FHHs for local maize and hybrid maize with and without fertilizer.

Indicator	Finding
Major impact of project	Hybrid maize and credit
Changes in food self-sufficiency	- 50% to 60% of all farmers say there is more food - 38% say there is less food
Income	- 54% say they have more income - 40% say they have less income - of these, FHHs (53%) and wives (51%) > MHHs (41%)
Inputs: seeds, fertilizer, machinery	- Greater usage MHHs (86%), wives (78%), FHHs (59%) - No change or use FHHs (41%), wives (21%), MHHs (15%)
Credit	Most farmers see use of credit as big change, but MHHs > FHHs
Marketing and transport	Most MHHs (83%) and wives (70%) see increases, but most FHHs (56%) see no change

Fig. 10. Perceived changes that are the result of the Lilongwe Rural Development Project (LRDP).

Indicator	Finding
Crops and livestock	Most households sell groundnuts FHHs (93%), MHHs (76%)
Sources of income	- MHHs derive more income from tobacco, chickens, hybrid maize - FHHs derive more income from bananas, eggs, local maize - Wives similar to MHHs but derive more income from sweet potatoes
Relative income from crops and livestock	- MHH income: 1) maize, 2) tobacco, 3) groundnuts - FHH income: 1) groundnuts, 2) maize
Nonagricultural income	- FHHs and wives – beer brewing - MHHs – some construction, artisan work, but agricultural income is main source for all

Fig. 11. Sources of household income.

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Crop/Livestock Systems

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CROP/LIVESTOCK SYSTEMS

Interactions among the crop and livestock components can have major impact on both biological and socioeconomic productivity from mixed farming systems. Examples of complementary interactions include the use of manure as fertilizer and use of crop residues as animal feeds. Competition most often occurs when scarce resources, such as labor and capital, are allocated to one component at the expanse of the other. Farming systems research addresses these interactions whether they are complementary or competitive.

The holistic approach of farming systems research also incorporates sociological as well as technical issues. What are the family needs? What are the family resources? Can existing resources meet needs in a timely manner? Maximization of economic return is often equated with maximization of utility. However, the value system of the family may be difficult to define in strictly monetary units. Hence, the challenge to the economic perspective is to consider family values (resources, constraints, traditions, risk, etc.) when evaluating alternatives for increasing farm productivity.

Papers presented in this section of the farming systems symposium reflect the "technical," the "sociological" and the "economic" views of mixed farming systems. The common thread is the effort of the authors to include these perspectives in developing a true systems approach to farming.

Hank Fitzhugh, Co-chair
Otto Loewer, Co-chair

ROBERT D. HART

Born in Michigan, Bob Hart was raised in eastern Ecuador by missionary parents. Returning to the United States, he studied biology, chemistry and ecology in Indiana. He returned to the Amazon area of eastern Ecuador where he conducted his master's thesis research on the effect of environmental factors on levels of prussic acid in cassava.

As a research assistant between 1971 and 1974, Bob conducted research on the design of bean, corn and cassava intercropping systems in Turrialba, Costa Rica. He obtained his doctorate in agronomy with an emphasis in crop ecology from the University of Florida, Gainesville.

As an agronomist, Bob worked with the U.S. Environmental Protection Agency developing managerial approaches for nonpoint-source pollution from agricultural land and prediction models that helped identify potential environmental degradation.

During the next three years (1976-1978), the Hart family lived in San Pedro Sula, Honduras, while he worked for the Centro Agronomic Tropical de Investigation y Ensenanza (CATIE) as Country Coordinator, directing a cropping-system-research project to identify alternative technology and developing a methodology for farm system analysis. From 1978 to 1981, he continued with CATIE in Costa Rica to conduct cropping systems research as well as share his knowledge, teaching a course on agricultural systems. A product of this course, his book Agroecosístemas, has been used as a textbook.

Bob then accepted his first position with the Winrock International Institute for Agricultural Development (then known as the Winrock International Livestock Research and Training Center). As an agronomist, he worked with the Small Ruminant Collaborative Research Project (SR-CRSP) in Kenya, conducting research that would develop feed technology for small-scale or limited-resource farm families who have a mixed (crop and animal component) farm unit. He also assisted in designing several farming systems projects in Brazil, Peru, Haiti and the eastern Caribbean.

While continuing his role as an agronomist, he and his family moved to St. Lucia, West Indies, where Bob was Chief of Party for the Eastern Caribbean Farming Systems Project (CARDI). During this time he developed a multidisciplinary project-management system that linked data analysis and the exchange of technical information among eight islands. In 1987, he returned to Winrock headquarters as a program officer for the Agricultural Systems Unit where Bob was instrumental in strengthening a positive working relationship between Winrock and the University of Arkansas.

Bob is presently the Director of the Rodale Research Center in Kutztown, Pennsylvania. He, his wife Joan and daughter Sarah make their home nearby.

AN ANALYTICAL FRAMEWORK FOR THE DESIGN AND EVALUATION OF CROP AND LIVESTOCK TECHNOLOGY

Robert D. Hart[1]

INTRODUCTION

When agronomists and animal scientists started doing on-farm research, they found that often good plot- or herd-level field- station technology could not be adopted by farmers unless they made substantial changes in their farm systems. On all farms, land, labor and capital must be allocated to different enterprises; however, on many farms this relatively simple competitive relationship among enterprises is made more complicated by biological linkages among enterprises. For example, on many farms in the Third World tropics, crop residue is an important source of animal feed, and animal manure and animal traction are critical crop-production inputs.

What makes agricultural-systems research different from traditional commodity and discipline-focused research is that techno-logical alternatives are selected because of their potential positive impact on specific agricultural systems. The potential alternatives are then evaluated by their impact on development. This requires an understanding of the link between the system that is the subject of physical and biological experimentation (e.g., a crop system) and the system that is the target for development (e.g., a geographic region).

Since farm systems are a key intermediate link between crops-and-livestock-level phenomena and regional-level phenomena, they are the focal point of many agricultural-systems-research projects. The fact that technology is selected because it fits into a farm system, and because its adoption is expected to have an impact on regional development, has important implications for research methodology. Research must be done not only to design and evaluate new technology but also to develop a framework linking the phenomena that are the subject of experimentation and the phenomena that are the targets for development.

This paper presents a process that can be used as a guideline to develop an analytical framework for development-oriented crop and(or) livestock research. The term "framework" rather than the term "model" is used because a key premise is that a set of descriptive interrelated data (i.e., a framework) is itself a useful tool. While the paper emphasizes the use of the framework as an analytical tool, the same data set is also an ideal starting point for more formal mathematical modeling.

[1]Director, Rodale Research Center, RD1 Box 323, Kutztown, PA, U.S.A.

The first section of the paper outlines the rationale for separating activities needed to develop an analytical framework from activities involving the actual design and evaluation of crop and(or) livestock technology. The second section describes a set of farm-system-component templates and a process for integrating them to form a farm or farm-subsystem framework. The third section is a case study from Dominica that illustrates how the analytical framework can be developed and used. The fourth section is a discussion of how an analytical framework can be used to design and evaluate technology.

FRAMEWORK DEVELOPMENT VERSUS TECHNOLOGY GENERATION

Agricultural research institutions in many Third World countries recognize the importance of developing more formal links between research and development. Scarce financial resources dictate that research priorities be based on real development opportunities. Emphasis is shifting from basic and applied research to strategic and adaptive research. In many countries, programs and pilot projects are directed at specific types of farms in specific ecological and socioeconomic environments. These projects are often called cropping systems, livestock systems or farming systems projects. Regardless of the name, these agricultural-systems-research projects share many common methodological needs and problems.

Development-oriented agricultural-systems research requires an understanding of the links between research and development, between research and extension, between biological and social sciences and between crop and livestock scientists. A formal recognition of the importance of these links is critical; each is briefly discussed next.

Integrating Research Objectives with Development Goals

One of the problems faced by scientists on systems-research teams is deciding which of many alternatives to choose as a research priority. Typically, the selection of a research bias (e.g., maize improvement) is made on the basis of available funds (a donor suggests a project or an international agricultural research center offers assistance) rather than on the basis of an objective analysis.

The first step in many projects is to undertake a reconnaissance of the area targeted for development. The reconnaissance usually identifies a list of "constraints." These "constraints," which are supposed to serve as a guideline for the first year of biological research, are often a mixture of observations that cannot be addressed without more analysis (e.g., soil "fertility") and factors that cannot be solved by biological research (e.g., poor transportation in the rainy season). Because the "constraints" that emerge from the reconnaissance are not easily converted into guidelines for experimentation, the

biological scientists often begin by conducting traditional field-station-type variety trials or livestock-breeding experiments. Menz and Knipscheer (1981) have termed this the "notional" stage of technology evaluation.

In the first year of most projects, the link between biological experiments and potential development impact is usually justified by "common sense" statements (e.g., higher yields could mean higher farmer income). The results of these experiments are often evaluated on the basis of the scientists1 perceptions (e.g., land is assumed to be the limiting farm resource); seldom are farmers' values (e.g., return per seed input or return to labor) explicitly considered.

In many projects, the potential development impact is not quantitatively considered in the design and evaluation of technology selected and tested in biological experiments. What is needed is an analytical framework that explicitly takes into consideration potential development impact.

Integrating Research and Extension

Development-oriented agricultural-systems-research projects explicitly recognize that the information flow between research and extension is much more complex than the transmission of an occasional recommendation from research to extension. Not only is the flow two way, with information flowing from extension to research, it is also multichannel, with a continuous updating of production constraints, development opportunities and alternative technology.

In order for researchers to know how to allocate their scarce financial resources, they need to know where there are opportunities that could lead to development. In order to successfully transfer technology to farmers, extension agents need to know not only a precise description of the alternative technology but also the type of farm system and the type of ecological and socio-economic environment where the technology has been shown to be effective. It is important to recognize that this is not a static information process. The ecological and socioeconomic environment is continuously changing (rainfall patterns change, prices change as new markets open) and new technology is continuously becoming available both from farmer selection processes and from formal research efforts.

Development-oriented research teams need an analytical framework that includes the type of information that links research and extension, and the information needs to be in a format that is flexible enough so that it can be continuously updated. Since researchers and extensionists are often in separate institutions or separate divisions of the same institution, it is often difficult to obtain formal agreement on a common analytical framework for research and extension. One approach is to seek closer coordination between the planning of research and

extension. However, even joint planning requires a common framework.

Integrating Biological and Social Science Disciplines

Development-oriented agricultural-systems research requires input from many different disciplines. Biological scientists with research experience with crops and (or) livestock are essential, but the direct participation of social scientists capable of both microeconomic and macrosocioeconomic analysis is also necessary. While it is easy to make general statements about the need for inputs from a broad range of disciplines, it is much more difficult to systematically identify the primary activities that need to be implemented by each discipline and to integrate the information generated by each discipline.

One of the strongest arguments for the need for an analytical framework is that it can integrate different disciplines. Social scientists must understand exactly why project resources are being used to conduct field-station trials to screen new varieties for shade tolerance. Biological scientists must understand why project resources are being used to conduct surveys to identify taste qualities demanded by potential markets. But the understanding must go beyond a perceived recognition of need for a certain type of information; it must involve recognition that the data from two disciplines can be complementary. For example, both shade tolerance and taste qualities may be important in selecting varieties for on-farm experiments.

If the results produced by two disciplines are going to be combined, such as by multiplying the average price of a commodity (in a given month in a specific market) by the average yield obtained by farmers, it is essential that the two scientists who are planning to combine their data have a common analytical framework. When a common framework has not been agreed upon, it is not uncommon, for example, to find economists doing labor-use studies with different crop or livestock systems than those that are being improved by agronomists and animal scientists. Often biological scientists are doing on-farm research with farmers who are very different from the farmers who are being monitored by social scientists.

Integrating Crop and Livestock Research

The emphasis of an agricultural-systems-research project may be on the development of either crop or livestock technology, or on both, but in many areas of the Third World tropics, farm systems have both crop- and livestock-production systems. When a farm system has many different crop- and livestock-production systems, and when there is a biological connection among crop and live-stock systems (e.g., crop residue fed to livestock or animal manure used as crop fertilizer), the selection and evaluation of either crop or livestock technology can become very complicated.

Recently, there has been considerable interest in the development of research methodology that takes into consideration interactions among crops (both food and tree crops) and livestock (McDowell and Hildebrand, 1980; Fitzhugh et al., 1982; Hart, 1985). A related methodological issue is the development of methodology for on-farm livestock experiments (Nordblom et al., 1985).

In order to formally take into consideration potential biological interactions among crop- and livestock-production systems, research teams need an analytical framework that includes the potential competitive, supplementary and complementary use of farm resources, as well as the potential flows of materials (crop residue, manure) and energy (animal traction) among crop and livestock systems. This framework is needed both as a guideline for the selection of technology to be tested and for the evaluation of potential impact on the farm system.

If a research team is trying to identify improvements for a livestock-production system on a crop/livestock farm and it must select forage species and the dates that they should be planted and harvested, the team needs an analytical framework that includes the date, quantity and quality of all available feeds (including crop residue) so that the introduced forage species will be harvested when feed is most limiting. If a team is trying to identify improvements for a crop-production system on a farm where animal energy is the primary source of traction, and it is seeking to introduce a new technology for land preparation and planting, the team needs to know the energy limitations of the oxen during the period prior to planting.

FARM SYSTEM AND COMPONENT TEMPLATES

Farm systems are composed of biological enterprises (crop- and(or) livestock-production systems) and household enterprises (postharvest storage, nonagricultural activities, etc.) to which farmers must allocate farm-level resources on the basis of expected returns (quantities as well as expected variance). At the same time they must consider potential off-farm uses of land, labor and capital. Farmers select technology by evaluating how it fits into the total farm system. For this reason farm system descriptions and farm-level models are an ideal framework for selecting technology for biological experimentation and evaluating the results.

It is difficult to make general observations about farm systems. Farms can be managed by individuals, a family, an extended family, a communal committee, a corporation, etc. These various types of farm-management entities can have various levels of control and access to land, labor, capital and information. Farm resources can be allocated to a wide range of production systems or to off-farm investments. This resource allocation can be

guided by a range of strategies as different as profit maxi-mization, food security and tax write-offs.

The wide range of potential types of farm systems makes it difficult to develop a farm-system analytical framework that can be used in all situations. Clearly each systems-research team must develop a farm-level analytical framework that reflects the salient characteristics of the predominant type of farm system in the area selected as a development target. Farms in a given region often have similar components (e.g., a maize/soybean cropping system), but the farms are different because of the inclusion of other components or differences in the relationships among components. This suggests that one approach to developing an analytical framework can be to design a set of component-level templates that can be combined to form different types of farm systems.

For an analytical framework to be useful, it need not always include a quantitative description of the entire farm system. While such a description is ideal, in most cases this type of analysis is expensive (in terms of research staff time). While less ideal, a qualitative understanding of the farm system and a quantitative description of a farm subsystem that includes the component targeted for research can be a useful analytical framework. The key components of this subsystem can be identified by beginning with the component that has been targeted for research (e.g., a tree-crop enterprise) and systematically identifying the other farm components that strongly interact with the target component.

The development of an analytical framework can be visualized as a two-phased process that involves different steps within each phase:

Phase I. Develop a qualitative farm-level framework. This is done by:

a. identifying the key components of the farm system and

b. identifying the pathways that link the key components of the farm system and the farm system inputs and outputs.

Phase II. Develop a quantitative farm-subsystem framework. This is done by:

a. identifying the farm component(s) targeted for research and the other farm components that directly interact with it (them),

b. developing and using data-collection instruments to describe the inputs, outputs and state of key farm components and

c. integrating the quantitative component descriptions to form a farm-subsystem analytical framework.

Earlier it was suggested that the purpose of this paper was not to argue the benefits of modeling. Emphasis has been placed on the need for a framework that includes interrelated descriptive data. However, the farm-level and farm-component-level templates described below are essentially the first step in the development of input/output models. It is important to note that there are inherent dangers associated with the deterministic characteristics of this type of model that need to be taken into consideration.

In the two-phase process described above, the quantitative frame-work is formed by combining component-level templates. This is done by assuming that outputs from one component are inputs to another. However, the data collected for the components is often collected at different times and under different conditions. When the templates are combined, it is easy to forget that the individual numbers are not nearly as deterministically related as the framework implies.

Qualitative Farm-system Framework

Figure 1 is a generalized qualitative diagram of a farm system. Most farms will not have all the components identified in the diagram. For example, to develop the diagram it was assumed that farms can include many types of crop, forage and herd components; in reality many farms do not have all three types of production systems. For the diagram it was assumed that farms can have the following types of components:

- a household
- capital exchange for purchased and solid inputs and outputs
- land and labor resource pools
- production systems for crops, forage and herds
- feed and manure storage
- crop and livestock product storage
- crop and livestock product processing.

The pathways that can connect these various types of components are also shown in the diagram. Once again, the diagram illustrates all possible links, all of which are not likely to be found on one farm. For example, the farm depicted in the diagram has crops, forage and herds linked by direct flows of forage and manure as well as by indirect links through storage components.

In addition to the pathways that connect farm production systems, the diagram also includes flows from land and labor resource pools to the various production systems. The diagram also includes the flows of land and labor from off-farm sources to the resource pool (farmer renting land and acquiring off-farm labor) and flows of land and labor away from the resource pools (farmer renting out his or her land and family labor obtaining off-farm employment.

Cash (liquid capital) flows in directions opposite to purchased inputs (including household and crop-and-livestock-production inputs) and to income-generating activities such as the sale of products or rent of resources (e.g., off-farm employment). Cash management can affect all farm enterprises. Cash availability over time affects a farmer's decision to grow a short-duration food crop or a long-duration tree crop. Cash availability also can affect a decision about how much to grow (a larger area can require more labor for land clearing, harvesting or application of fertilizer). The selection of specific farm enterprises (crop or livestock) can affect cash flow by the timing and ease with which they can be sold. For example, small animals can be more easily converted into cash (and therefore contribute to the liquidity of a farm) than can most crops.

The diagram depicted in Fig. 1 can be used as a guideline for drawing a diagram that represents the components, component links and farm inputs and outputs. When such a qualitative framework has been developed, the next steps are 1) to develop a quantitative description of the key farm system components and 2) to develop a quantitative framework that can be used to identify and evaluate potential technology within the key components.

The farm components selected will depend on the phenomena target-ed for research and the interactions between the target farm component and other components. Many projects begin with the target farm component already selected during the design of the project. In these situations the next step is to evaluate the interactions between this component and other farm components. One danger is to place too much attention on relatively weak interactions and spend too many resources analyzing too many phenomena that only marginally affect the target farm component. Another danger is to neglect an interaction that can affect the potential adoption of new technology.

The following section describes a set of microcomputer templates that can be used to describe farm system components. Templates to describe farm land, crop systems, forage systems, herd systems and feed storage components have been selected to illustrate this step in the development of an analytical framework because they are critical farm components in the crop/livestock-research case study described in the third section of this paper. Templates to describe other components, such as farm labor and manure storage, can be developed by using the format the paper presents for the selected farm components.

Component Templates

Figure 2 is a printout of a microcomputer-based spreadsheet that can be used to tract inputs, outputs and availability of land in a farm system. It was assumed that in many situations it will be necessary to classify land by different production-potential criteria. These classification criteria are not noted since they

are likely to vary by farm situation. Example of land-classification criteria are slope, physical structure, fertility, moisture levels, etc.

In the template described in Fig. 2, it is assumed that land inputs can be owned by the farmer, formed on a sharecropper basis, rented or acquired through other means (e.g., communal land, road sides, etc.). Land use is classified by the components shown in Fig. 1. Equations in the spreadsheet calculate total land input, total land use and land in fallow. The acquisition and use of land over time is arbitrarily divided into 1-month increments, but this can easily be changed to quarterly, annual or any other more appropriate time interval.

Figures 3 and 4 are printouts of microcomputer-based spreadsheets that can be used to tract inputs, standing biomass and outputs from a crop-production system and from a forage-production system. The inputs, standing biomass and outputs can all be described either by a yearly total or by monthly variations. In these templates, it is assumed that these variables should be measured in monthly intervals, but in many situations quarterly or annual intervals would be more appropriate. For example, tree crops need to be described using different time intervals than those used for annual crops.

Inputs include land, labor associated with all inputs, animal and mechanical traction energy, seed, inorganic and organic fertilizer, pesticides, irrigation and precipitation and solar radiation. As already noted, most crop-production systems will not have all these inputs; the list is intended as a guideline for identifying the real inputs.

Standing biomass is described in both templates in dry weight quantities (kilogram/hectare) and in quantities of nitrogen, phosphorous and potassium. In many situations different descriptors may be more appropriate. For example, crop biomass could be separated into roots, stems, leaves, fruits, etc. Often the percentage of protein or lignin may be an appropriate description for forage-production systems. In the analysis of many crop-production systems, standing biomass is not an important parameter; the amount and the quality of the biomass at harvest are the only data needed. In that case the standing biomass section of the template would be left empty.

The outputs from the crop- and forage-production systems are separated by crop species and within crop species by yield and residue compartments. These two compartments are arbitrary subdivisions; if a farmer produces a grain crop and plans to eat the grain and use the stover as livestock feed, it is logical to measure the yield of the stover as well as of the grain. As suggested above, the subdivisions made in this generalized template are intended only as guidelines to selecting appropriate quantitative and qualitative measurements of production-system outputs.

Figure 5 is a printout of a microcomputer-based spreadsheet that can be used to tract inputs, standing biomass and outputs from a livestock production system. The inputs, standing biomass and outputs can all be described as a yearly total or by monthly variations. As in the case of the templates described above, it is assumed that the appropriate chronological measurement of these variables is by monthly increments, but obviously herd dynamics are often more appropriately described using a quarterly or an annual distribution.

Inputs include land, labor associated with all inputs, live male and female animals of various ages, veterinary products, semen, infrastructure to house and confine the herd and feed from various sources. Once again, most herd-production systems will not have all these inputs.

In the template, standing biomass is described in terms of number of animals in various categories, weight of animals in the categories and the feed demand generated by the herd categories and the herd as a unit. Different herd structures generate different input demands and produce different outputs. Animal scientists tend to approach this structure/function relationship by making assumptions about the herd structure and then identifying needed inputs and expected outputs. Forage agronomists and veterinarians tend to begin with the inputs and then identify appropriate herd structures. Farmers manage herd structure and input and output simultaneously. The template described in Fig. 5 assumes that feed demand is a function of animal weights in different categories (e.g., lactating and nonlactating females). Feed input, feed demand or both can be changed.

The outputs from the herd-production system are separated by live and dead animals of the different categories that make up the herd and by animal products such as milk and manure. The "live" and "dead" categories can be used to distinguish between animals that die and herd off-take. In the template, the manure output is described as if its primary value is as fertilizer; if the manure is used for fuel, an energy valuation would be more appropriate.

Linking Templates to Form an Analytical Framework

After the key components of a farm system are described quantitatively, the next step is to integrate the component-level descriptions to form an analytical framework. Since the key components are selected on the basis of their interactions with the target research component, it is relatively easy to integrate component descriptions.

In the case of the five farm components (land, crops, forage, livestock, feed storage), the outputs from the land component are inputs to the other components, the outputs from the crop- and

forage-production systems are inputs to the feed-storage system, and the outputs from the feed-storage system are inputs to the herd system. If the templates used to describe the components are designed correctly, the outputs from one component and the inputs to another should be in a common unit measured over a common time interval with a common frequency.

The usefulness of an analytical framework based on a set of integrated farm components can best be discussed by presenting a case study based on a real farm situation. The case study illustrates how an analytical framework formed by combining herd, forage, manure storage and crop components can be used to select and evaluate both crop and livestock technology.

CASE STUDY FROM DOMINICA, WEST INDIES

The Caribbean Agricultural Research and Development Institute (CARDI) has done extensive research to identify alternative technology for farmers on the island of Dominica. Figure 6 is a generalized qualitative diagram of a farm system in the area of Morne Prosper. The predominant enterprises found on farms in this area are bananas and banana-based crop systems, root crops (yams, dasheen, tannia, etc.), vegetables (cabbage, tomatoes, carrots, etc.) grazing areas (unimproved pastures) and dual-purpose (milk and meat) cattle. Land and labor resources are allocated to these enterprises, and cash acquired through the sale of bananas (the most important cash crop), animal products, vegetables and root crops is used to purchase household requirements, off-farm labor, crop inputs (fertilizer, seeds, etc.) and livestock inputs (veterinary products, salt, etc.).

The technology being tested by the CARDI Farming Systems Research and Development (FSR/D) project requires farmers to add two enterprises: intensive production of elephant grass and confined livestock. These two enterprises do not replace the extensive grazing area and extensive cattle herd. Instead, farmers have combined the existing with the new to form a six-component livestock-production system (Fig. 6). The components are linked by flows of feed from the forage area to the herds and by the movement of animals between the intensive (grazing) and extensive (confined) herds. In addition, the livestock are closely linked to the vegetable enterprise through a flow of manure from the confined herd.

Approach

The six-component farm subsystem defined in Fig. 6 was analyzed using forage, herd, manure and crop templates such as those described. To analyze the six-component farm subsystem in Morne Prosper, the forage-production template was used to describe the extensive grazing area and the elephant grass area, the herd-system template was used to describe the extensive herd and the intensive (cut-and-carry) herd, the crop-production template was

used to describe vegetable production, and the manure-storage template was used to link the cut-and-carry herd with the vegetables.

When the templates were filled in with existing data, it was found that in many cases data were not available. In some cases, data were estimated from the literature (e.g., crude protein of elephant grass). In other cases preliminary "guesses" were entered. In the right-hand column of each template, the source of the data for each row of data was noted.

In addition to each template being filled in with the inputs, standing biomass and outputs, it was modified to reflect the specific characteristics of the six components. In the extensive grazing template the natural productivity was defined as a function of the previous month's rainfall (no monthly-productivity data was available). The amount of forage removed was defined as a function of the length of the tethers used to stake out the animals, the number of animals grazing and the natural productivity of the vegetation. In both the extensive forage area and the intensive elephant grass area, the percentage of moisture of the vegetation when harvested was not known and had to be estimated (guessed).

In both livestock-herd templates (extensive and intensive), the categories of cattle were defined as calves 0-6 months, calves 6-12 months, heifers, dry cows, milking cows and bulls. In the template, the average weight of each category of animal for each month must be filled in. However, reliable data were not available, and the weights were estimated and maintained constant throughout the year, although it is known that weight loss often occurs during the dry season. The template calculates feed demand by multiplying the number of animals in each category each month times the average weight times a constant. The constant is the Meal of digestible energy needed for each kilogram of body weight for each category of animal.

The CARDI Dominica country team has done considerable research on elephant grass production, so the template used to describe this component was easier to fill in. Although fresh weight estimates of productivity and the amount of area cut by farmers each month were available, dry weight productivity estimates were not available. Since crude protein and digestible energy production were defined on a dry-weight basis, the lack of reliable dry weight estimates is undoubtedly the most serious "missing information."

The elephant grass template was modified to include a measurement of the area with grass less than 1 month old, the area with 1- to 2-month-old vegetation, and the area with vegetation more than 2 months old. It was assumed that farmers cut 1- to 2-month-old grass. The area cut one month becomes 1 month old next month, and 1-month-old vegetation (unless cut) becomes 2 months old the following month. The actual area cut by farmers is determined by

the feed demand of the confined herd (which in turn is a function of herd structure) and the productivity of grass (i.e., less area must be cut if production/area is high).

When the six templates had been filled in, they were combined to form one spreadsheet. The outputs from the grazing and elephant grass templates were linked to the inputs of the extensive and intensive herds. The two herd templates were linked through the movement of live animals. For example, the live animals moving out of the confined herd to the extensive herd were defined as outputs of the intensive herd and inputs to the extensive herd. The output of manure from the cut-and-carry herd was an input to manure storage, while the output from the stored manure was an input to the vegetables.

Preliminary Evaluation

During the early phase of developing an analytical framework such as that just described, there are always large gaps in available information. The first step in evaluating the quality and potential usefulness of a framework is to evaluate the internal consistency of the data and preliminary assumptions. In Dominica, the CARDI team began the evaluation of the preliminary framework by graphically comparing data sets that would be expected to be related. Most spreadsheet programs allow the user to observe graphic output on the computer screen without printing the graphs.

One of the first evaluations of the internal consistency of the Dominica analytical framework was done by graphing the digestible energy value of the grass cut from the elephant grass area and the digestible energy demand from the confined herd (Fig. 7). The two curves are calculated from different sets of data (fresh weight cut by a farmer and herd structure). The two sets of data are from two different component templates (a forage template and a herd template) that were filled in by two different CARDI scientists. Assuming that the remarkable similarity of the two functions is not simply a coincidence, the graph indicates that, even with all the information gaps, the basic assumptions made about the relationship between the elephant grass component and the confined herd are probably valid.

Another example of internal consistency made by the CARDI team was a comparison of the manure produced by the confined herd and the manure used as fertilizer on vegetables. The amount of manure produced was estimated by multiplying the number of head in the herd each month by the quantity of manure per animal that was obtained during a short-term study. The amount of manure and time of application to vegetables were estimated by interviewing a farmer and asking how many bags of manure were used on each vegetable plot. A preliminary evaluation suggested that the total quantities produced and used were similar, but a better understanding of manure storage and management was needed.

The analytical framework being developed by CARDI in Dominica is still in its initial phase. The team has identified the data that is needed before the framework can be used as an effective tool to identify and evaluate technology. But even at this stage, the value of the framework is apparent. For example, the framework indicated that the livestock technology being developed and adopted by farmers had the potential to increase farmer income from vegetables.

USING AN ANALYTICAL FRAMEWORK

Like most modeling efforts, the development of an analytical framework is a never-ending process. As more research is done, weaknesses will be identified, hypotheses changed and the analytical framework continuously updated. In most cases the primary uses of an analytical framework are selection of potential technology and evaluation of the impact of new technology. Another potentially important use could be in selecting farmers who could benefit from the technology. These uses are discussed briefly.

Design of Experiments

Agronomists and animal scientists, by training, tend to design experiments to test hypotheses at the level of an individual crop or livestock population. For example, agronomists test different crop varieties or different planting densities by measuring yield; animal scientists test different feed supplements or different animal breeds by measuring animal performance such as growth or milk production. Often the questions addressed are of interest to individual disciplines but do not produce the information needed to design alternative technology that can have a development impact.

An analytical framework can be used to evaluate the relevance of an experiment. An analytical framework developed by a small ruminant project in Western Kenya was used to design feed interventions that had a high probability of having an impact on the livestock (Hart et al., 1984). During the first year of research, the agronomists designed experiments that identified high-forage-producing interventions, but the increased production often occurred at the same time feed was already available. The analytical framework helped the team concentrate on finding interventions that produced feed when it was limiting rather than when feed production could be maximized. The team also began to emphasize feed preservation as well as production.

Evaluation of Experiment Results

The same analytical framework used to select treatments to be included in an experiment can be used to evaluate experiment results. The selection of evaluation criteria is one of the most difficult problems faced by agricultural systems research teams.

Crop yield area, total animal product produced in a year or economic return from one enterprise are not always the most relevant criteria. Results should be evaluated on whether a farm performs better with or without the new technology, not on how the technology performs in a vacuum.

An analytical framework can be used to help biological scientists and economists take into consideration interactions among production systems when they evaluate experimental results. If a new technology requires more labor than does a farmer's present technology, the critical question is not simply whether the new technology gives a higher return per unit of labor input within the target production system. The key question is whether farm-level return to labor is higher or lower with the new technology.

McDowell (1985) sites evidence to indicate that often new higher-yielding grain-crop varieties produce stover with lower digestibility than do older, lower-yielding, traditional varieties. On farms where crop stover is an important feed resource, the evaluation of crop experiments must include not only grain yield but yield of digestible forage. An analytical framework that includes crop/livestock interactions (where they are important) can help a research team identify the correct criteria that should be used to evaluate experimental results.

Selection of Target Farms for Technology Transfer

Technology transfer is often conceptualized as the communication of production constraints by extension agents to researchers and the communication of technical recommendations from researchers to extension agents. But the communication between extension agents and researchers involves more complex information than simply "disease X is a problem" and "new variety Y should be recommended to farmers."

In many areas of the Third World tropics, there are many different farm systems; within each farm system, there are many different production systems; within each production system, there is more than one species of crop or livestock. In these situations, it is not enough simply to identify "constraints" and make "recommendations." It is important to know on what type of farm a constraint has been identified and on what type of farm and production system a recommendation has been tested and found valid.

An analytical framework can perform a vital function by improving the communication between research and extension. As extension and research collaborate in the first phases of agricultural system research, they can together develop the farm-level qualitative framework (Fig. 1) that will guide the development of a quantitative framework. When research results are promising and extension participates in evaluation of the new technology, the analytical framework can be used to identify the farm characteristics where the new technology will have a high

probability of being adopted and making an impact.

While the development of an analytical framework is an important activity for a research team, it should be noted that a framework without alternative technology is of no value. An analytical framework is only a tool, not an end in itself. However, there is no doubt that an analytical framework can be an important tool. In many agricultural-systems projects it is appropriate to clearly distinguish between activities to develop an analytical framework and activities to identify and test technology. But it must be remembered that the objective of both types of activities are to contribute to an integrated, development-oriented, research-and-development process.

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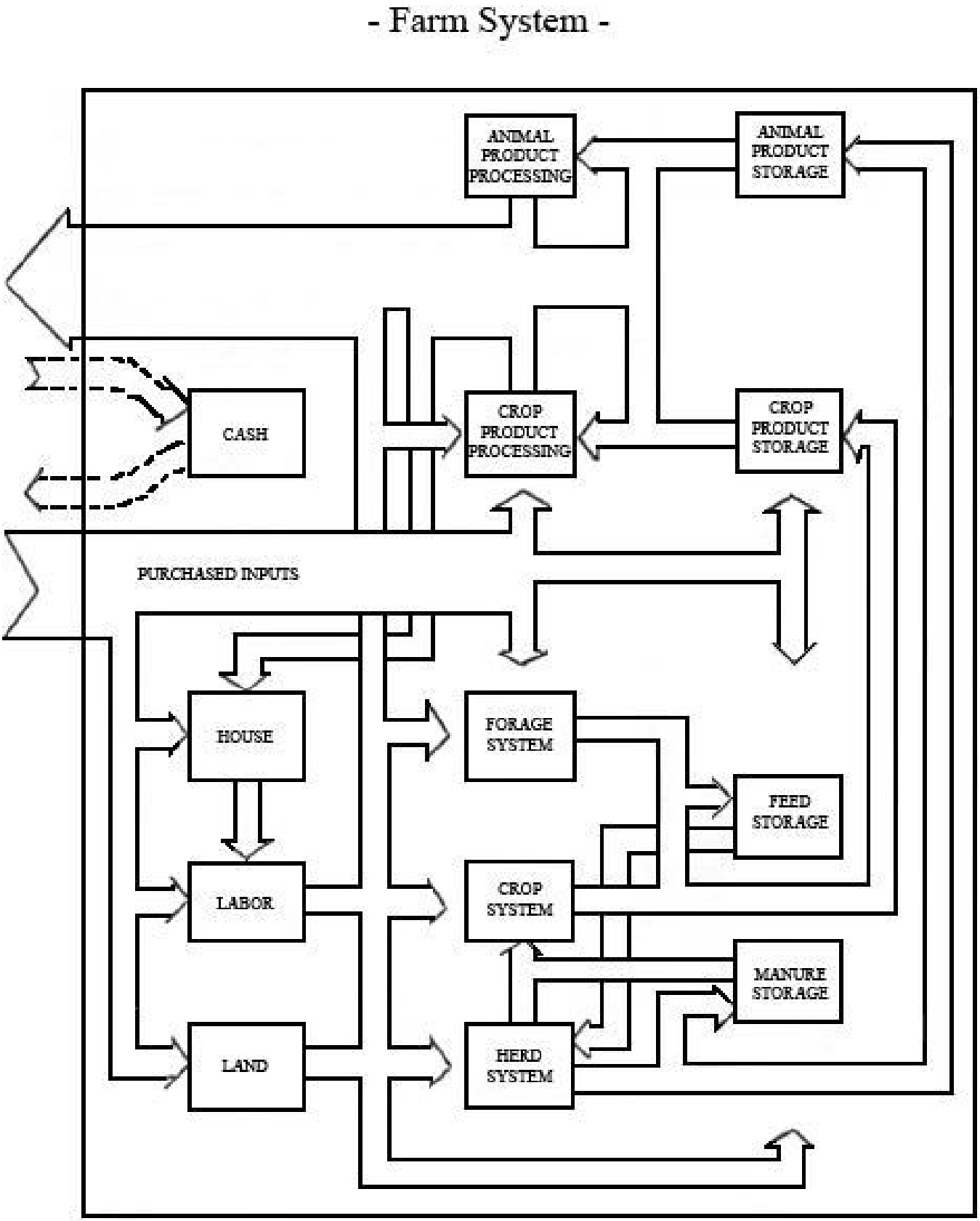

Fig. 1. A generalized qualitative diagram of a farm system with 13 types of components

FARM LAND	Units	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
INPUTS														
-Farmer owned	units													
--type 1														
--type n														
-Share cropped	units													
--type 1														
--type n														
-Rented	units													
--type 1														
--type n														
-Other arrangement	units													
--type 1														
--type n														
Total Land Input	units													

Available Land	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
*Type 1													
*Type n													
Total Land													

OUTPUTS	Units	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
-Rent to other	units													
--Type 1														
--Type n														
-Household	units													
--Type 1														
--Type n														
-Crop System n	units													
--Type 1														
--Type n														
-Crop System n	units													
--Type 1														
--Type n														
-Forage System 1	units													
--Type 1														
--Type n														
-Forage System n	units													
--Type 1														
--Type n														
-Herd System 1	units													
--Type 1														
--Type n														
-Herd System n	units													
--Type 1														
--Type n														
-Feed storage	units													
--Type 1														
--Type n														
-Manure storage	units													
--Type 1														
--Type n														
-C & L prod str	units													
--Type 1														
--Type n														
Total land used	units													
--Type 1														
--Type n														
-Fallow	units													
--Type 1														
--Type 2														

Fig. 2. A printout of a microcomputer-based spreadsheet that can be used to track inputs, available land and outputs from the land resource component of a farm system (see Fig. 1 to see relationship to other farm components).

CROP SYSTEM X	Units	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Inputs														
-Land	units													
-Labour	units													
--land prep														
--plant crop 1														
--plant crop n														
--weeding														
--apply fertile														
--apply manure														
--apply pestic.														
--apply irrigate														
--harvest crop 1														
--harvest crop n														
-An. tract; units:	units													
-M. energy; units:	units													
-Seed crop 1	unit													
-Seed crop n	units													
-Fertilizer:														
--Nitrogen (N)	units													
--Phosphorus (P)	units													
--Potassium (K)	units													
-Manure														
--Nitrogen (N)	units													
--Phosphorus (P)	units													
--Potassium (K)	units													
-Pesticide	units													
-Irrigation	units													
-Precipitation	units													
-Solar Radiation	units													
-Infrastructure	units													
-other input	units													

Plant Biomass	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
*Crop 1													
**dry wt													
**N													
**P													
**K													
*Crop n													
**dry wt													
**N													
**P													
**K													

OUTPUTS	Units	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Crop 1														
-yield; units:														
-residue; units:														
--dry matter														
--Nitrogen (N)														
--Phosphorus (P)														
Crop n														
-yield; units:														
-residue; units:														
--dry matter														
--Nitrogen (N)														
--Phosphorus (P)														
--Potassium (K)														

Fig. 3. A printout of a microcomputer-based spreadsheet that can be used to track inputs, standing biomass and outputs from a crop-system component of a farm system (see Fig. 1 to see relationship to other farm components).

FORAGE SYSTEM X	Units	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
INPUTS														
-Land	units													
-Labour	units													
--land preparation														
--plant crop 1														
--plant crop n														
--weeding														
--apply fertilizer														
--apply manure														
--apply pesticide														
--apply irrigation														
--harvest crop 1														
--harvest crop n														
-An. trac units	units													
-M. energy units	units													
-Seed crop 1	units													
-Seed crop n	units													
-Fertilizer														
--Nitrogen (N)	units													
--Phosphorus (P)	units													
--Potassium (K)	units													
-Manure														
--Nitrogen (N)	units													
--Phosphorus (P)	units													
--Potassium (K)	units													
-Pesticide	units													
-Irrigation	units													
-Precipitation	units													
-Solar radiation	units													
-Infrastructure	units													
-Other Input	units													

Plant Biomass	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
*Crop 1													
**dry weight													
**N													
**P													
**K													
*Crop n													
**dry weight													
**N													
**P													
**K													

OUTPUTS	Units	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Crop 1														
-yield units														
-residue units														
--dry matter														
--Nitrogen (N)														
--Phosphorus (P)														
--Potassium (K)														
Crop n														
- yield units														
-residue units														
--dry matter														
--Nitrogen (N)														
--Phosphorus (P)														
--Potassium (K)														

Fig. 4. A printout of a microcomputer-based spreadsheet that can be used to track inputs, forage systems and outputs from a crop-system component of a farm system see Fig. 1 to see relationship to other farm components).

HERD SYSTEM X	Units	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
INPUTS														
-Land	units													
-Labour	units													
--feeding														
--moving animals														
--apply vet prod														
--maint infrastructure														
--milking														
--collect manure														
-Live animals	units													
--juvenile females														
--juvenile males														
--adult females														
--adult males														
-Vet prod type 1	units													
-Vet prod type n	units													
-Semen	units													
-Infrastructure	units													
-Feed														
--from storage														
--from forsys 1-n														
--feed supplement														
--other inputs	units													
--total feed														
-Feed Excess														

HERD INVENTORY	Units		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
*Number of Head														
**juvenile females	#													
**juvenile males	#													
**lactating females	#													
**nonlac adult females	#													
**adult males	#													
*Mean Weigh														
**juvenile females	Kg													
**juvenile males	Kg													
**lactating females	Kg													
**nonlac adult females	Kg													
**adult males	Kg													
*Feed Demand		Mcal/Kg	Mcal/yr											
**juvenile females														
**juvenile males														
**lactating females														
**nonlac adult females														
**adult males														

OUTPUTS	Units	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
-Dead Animals														
--juvenile females														
--juvenile males														
--lactating females														
--nonlac adult females														
--adult males														
-Live Animals														
--juvenile females														
--juvenile males														
--lactating females														
--nonlac adult females														
--adult males														
-Animal Products														
-Milk														
-Manure														
--Nitrogen (N)														
--Phosphorus (P)														
--Potassium (K)														
-Other														

Fig. 5. A printout of a microcomputer-based spreadsheet that can be used to track inputs, herd systems and outputs from a crop-system component of a farm system (see Fig. 1 to see relationship to other farm components).

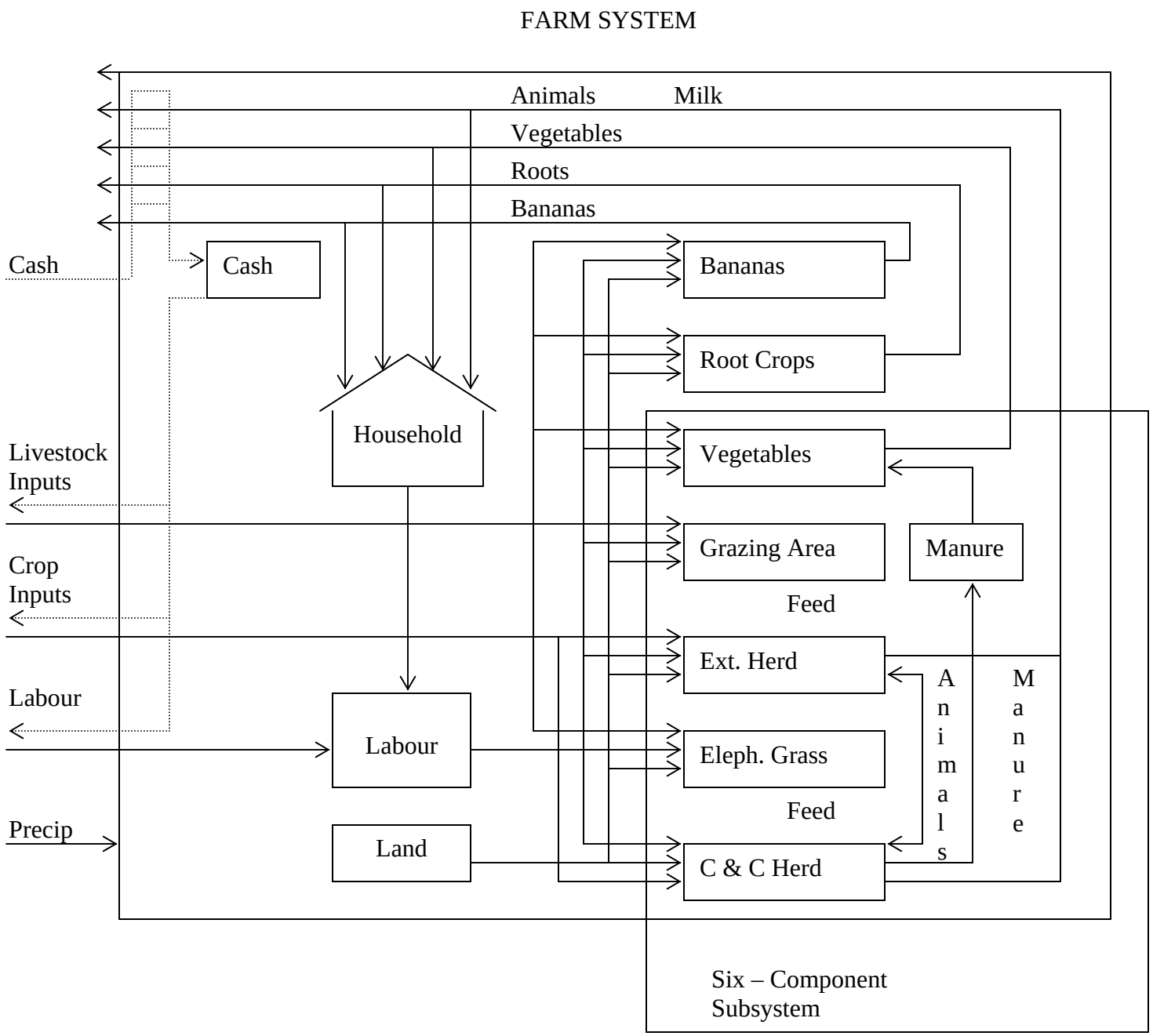

Fig. 6. A six-component subsystem used as an analytical framework for crop/ livestock research by the Caribbean Agricultural Research and Development Institute in the Morne Prosper area of Dominica, West Indies.

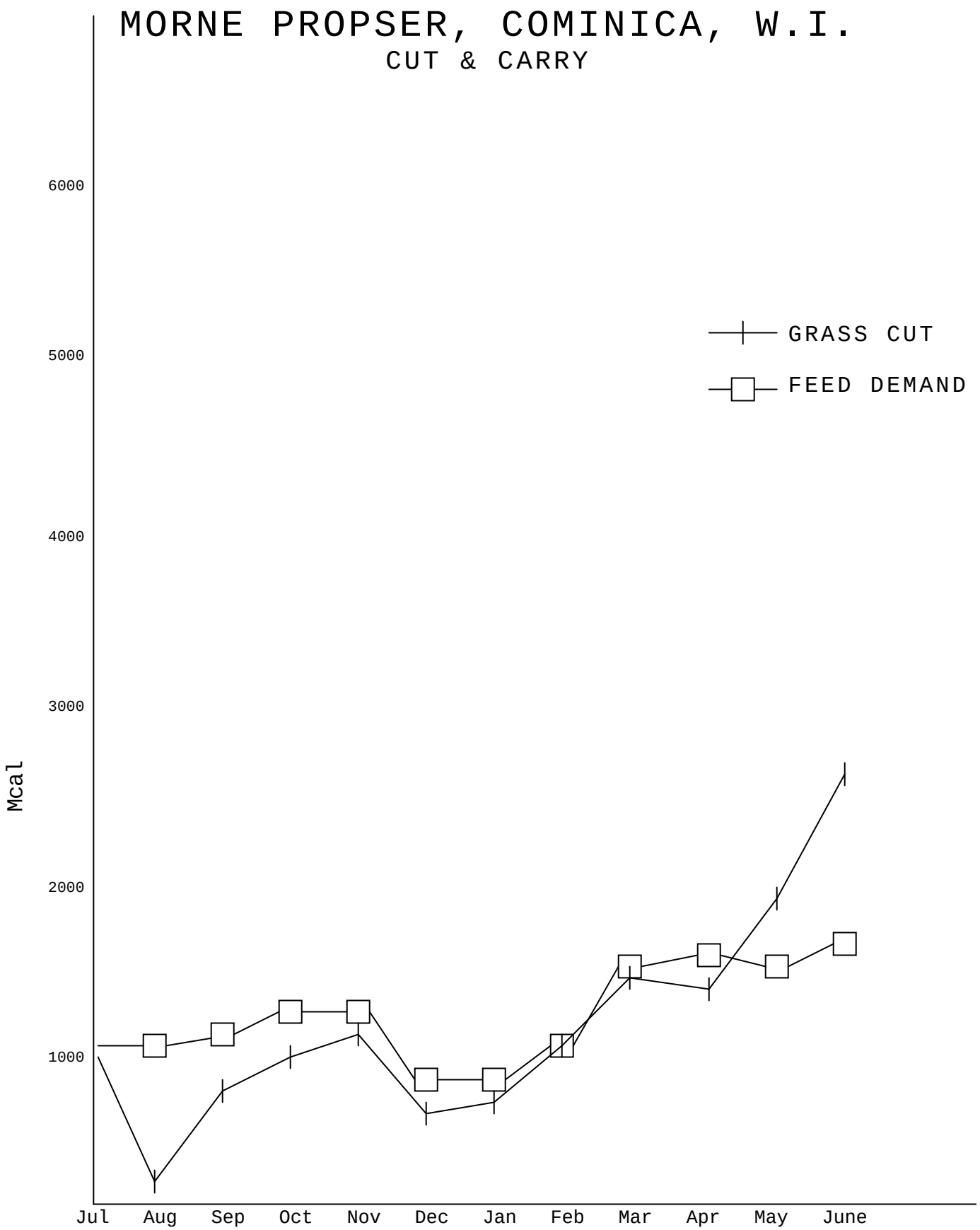

Fig. 7. Monthly digestible energy available from elephant grass cut and energy needed by a cattle herd on a farm in Morne Prosper, Dominica, West Indies.

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A STRATEGY FOR TECHNOLOGY TRANSFER TO CROP/LIVESTOCK PRODUCTION SYSTEMS IN SELECTED REGIONS OF MOROCCO

R. E. Banner, P. Bartel, C. V. Gay and D. L. Nolte[1]

INTRODUCTION

Livestock production on communal rangelands of Morocco is of central importance to the agricultural economy of the country. Forty-five percent of the rural poor live in the mountain and semiarid regions where communal rangelands are a major source of forage and livestock production is preeminent (Crawford and Purvis, 1986). The sustainable natural resources of these regions are undergoing serious degradation due to a number of factors including many related to population increase and inherent land productivity limitations. This, as well as the existing level of poverty experienced by the crop and livestock agriculturalists of these regions, served as the justification for a project engaged in on-farm research and extension activities to improve the situation.

Project personnel from the Moroccan Livestock Service (DE) and Utah State University adopted a three-part strategy for improving the well-being of agropastoralists dependent on rangelands under the auspices of a range management project sponsored by the United States Agency for International Development (USAID). The three basic components of the strategy were

- gathering primary information about the structure, operation and output of production systems to improve understanding of existing problems;

- identifying alternative range and livestock management practices that would reduce constraints;

- developing strategies and programs for transfer of this technology to individuals and groups of agropastoralists.

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[1]Authors are former Utah State University Chief of Party, Research Associate, Assistant Chief of Party and Research Associate; respectively, of the Range Management Improvement Project, Rabat, Morocco.

The Range Management Improvement Project (USAID Project 608-0145) was funded as a host-country contract between the Livestock Department of the Ministry of Agriculture and Agrarian Reform, Government of Morocco and the Range Science Department, Utah State University, Logan, Utah, U.S.A. 84322-5230.

This approach to range and livestock production problem identification and solving was similar to the farming systems research and extension approach commonly used in situations where agronomic crops are of central focus (Lang, et al., 1984). Cook and others (1984) applied a philosophically similar approach to development in a livestock production system in Sudan. Through implementing such a strategy, technicians gain better understanding of the production systems based on quantified social and biological information. This allows concentration of project efforts and resources on assessing technical interventions to address important problems. With improved management practices quantified, technicians can initiate extension programs directed at solving problems recognized by agropastoralists.

RESEARCH SETTING

The Kingdom of Morocco is located in northwestern Africa, across the Straits of Gibraltar from Spain. Climatic conditions in the country range from moist and temperate in the north to alpine in the Atlas Mountains and arid in the southeastern parts of the country. A great deal of heterogeneity is found among the people as well, with the Arab and Berber tribes forming distinct ethnic and linguistic groups.

The research domain of the study (Wotowiec et al., 1986) included three regions in a semiarid zone of Morocco that occurs between 33° and 34° north latitude from the Middle Atlas Mountains east to the High Plateau (Fig. 1). The three geographic regions include a mountainous area around the village of Timahdite in Ifrane Province a foothill and plain area including the El Faija Grazing Perimeter in Missour Province, and a plain around the town of Ain Beni Mathar in Oujda Province. Salient environmental characteristics of these regions are presented in Table 1. The three study sites represent a geographic band that extends from the Algerian border, an area of mesas and alluvial plains dominated by sagebrush (Artemisia herga-alba) and esparto needlegrass (Stipa tenacissima which is called "alfa-grass locally), to the western slopes of the Middle Atlas Mountains, where the landscape is broken with distinct zones of oak (Quercus spp.) forests, perennial grasslands and shrublands dominated by Thymus capitatus and Genista spp.

RESEARCH OBJECTIVES

All research activities were directed toward increasing agricultural production and profit for Moroccan livestock producers. From 1984 through 1986, technicians working with the USAID-funded Range Management Improvement Project conducted studies of the production systems to

- identify system characteristics and production constraints (system structure, operation and output) and

- evaluate alternative production practices.

Since little detail or specific information was known about systems, constraints and levels of production at the individual producer level,

clear definition of producer problems was the area of greatest research emphasis.

Just as the due consideration of livestock is important in farming systems research and development in crop-dominated systems (Bernsten et al., 1984), it is equally important to evaluate all aspects of livestock-dominated production systems, including agronomic components. Although the Range Management Improvement Project was not formally planned as a farming systems research and development project, it was necessary to take a farming systems research approach to understand how the production systems functioned and to identify specific problems that could be addressed. Project technicians used farming systems research techniques to define and document basic animal and crop production problems. Trials to evaluate range and livestock management practices that held promise for addressing producer problems were initiated as production problems were better understood. Consequently, there was a time-lag from when problems were recognized and understood to when trials to evaluate new technology could be initiated. This slowed the process but increased the relevance of the adaptive research. The short timeframe of the project precluded completion of many trials that required time spans of several years, such as experiments for evaluation of range improvement practices involving perennial plant species (shrubs or perennial grasses). However, project technicians planned and implemented multiyear experiments as if the project would continue. The total responsibility for evaluating these experiments over time passed to local technicians when the project ended. Based on knowledge of local production systems gained through biological and sociological research at the producer level, project technicians developed strategies for introducing new technology as positive results became available.

Project staff worked with 8 to 15 producers at each of the three study sites. These producers were known by project technicians from the Livestock Service for their cooperative attitudes and participation in livestock production-related programs. This sample represented the range of producers by herd size and land ownership categories. Landless producers were not well represented in the sample; however, these small producers were often herders for larger producers, and their herd management practices were reflected in those of their employers.

Technicians conducted on-farm adaptive research on herd management (selective breeding, animal selection, early weaning and animal health) and range management (revegetation, grazing management and erosion control). In concentrating part of the research effort on improving herd management, the goal was to improve producer profit quickly with low-cost technology. Technicians felt that such an approach was needed to build credibility with producers so that they could eventually introduce range management practices that required producer organization, cooperation and long-term commitment to improving the management of communal rangelands.

The findings of these studies provided estimates of present production parameters. From these estimates, project staff hoped to identify key problems and make projections of the effects of adopting improved herd management techniques and range improvement on individual production

units. Although they realized that the crop production component of the production system is integral to the overall system, project emphasis was on livestock production. Most of the harvested crops were used by producers to support livestock-production activities.

RESEARCH RESULTS

The rural population of Morocco comprises *56%* of the total population of the country. At the three research sites, the population can be characterized as conservative, continuing to follow a traditional lifestyle. Nevertheless, the population has been profoundly affected by recent technological developments such as advances in mass communications technology, which have made rural people acutely aware of current events in Morocco and the world.

Two major cultural groupings are found in the semiarid zones of Morocco, the Arabs and the Berbers. Though sharing a common religion, Islam, their linguistic roots are unrelated. Further, their social structure differs, particularly in terms of the visibility and assertiveness of women in the community. Arabic is the official language of the kingdom, and French is the working language of the Ministry of Agriculture and Agrarian Reform. The majority of the people speak an unwritten Moroccan dialect of Arabic. Further, many rural Berbers speak only one of several distinct Berber dialects.

The rural population is organized into a hierarchic tribal structure that is based on an oft times mythical lineage. Before the French and Spanish Protectorates began in the early 1900s, these tribes exerted considerable control over the lands they occupied and provided social cohesiveness. Much of the tribal power was removed during the Protectorate, and tribal authority has continued to decline since national independence in 1952.

The tribal structure plays a role in the government of rural areas through rural communes with an elected president and council. In addition, there exists a direct government structure under the Ministry of Interior, headed by a "caid" at the level of the rural commune and "shiekhs" and "muqqadem" at lower divisions of the tribe. Tribal membership determines access to the communal rangelands controlled by the tribe and can be acquired, over time, in some areas.

The communal nature of tribal rangelands is of central importance to livestock production and the implementation of range management in Morocco. Open access by tribal members, combined with the lack of control of range use has resulted in continuous degradation of the resource as the human population has increased. Further, some of the rangeland is subject to conflicting claims of ownership by various tribes. Thus, even if a method of control is implemented by one tribe, another tribe with conflicting claims to the same land may violate this with relative impunity. Such conflicts have given rise to a considerable amount of strife and legal action, including occasional instances of violence.

Two forms of private land ownership exist. A modern system of entitlement to land was introduced by the French. This form of land ownership exists primarily in those productive agricultural areas that have a more developed infrastructure, such as irrigation schemes developed by the government, or in lands that have been redistributed under the agrarian reform. A more traditional form of private land ownership is quite similar to the concept of homesteading. Through continuous cropping, land eventually becomes the property of an individual. This form of privatization of land has contributed to the increased cultivation of marginal land and subsequent decline in productivity and area of communal rangelands.

Land ownership tends to be quite highly concentrated. For example, 3% of the population owns more than 25% of the land in the Timahdite area. Most families own some land; however, irrigated land holdings are often very small. A survey of 157 families (13% of the population) conducted in 1985 at Timahdite showed that nearly 62% of those families have less than 5 ha of irrigated cropland while slightly more than 3% have farms larger than 40 ha (Table 2). Over 72% of the producers have dryland holdings of less than 5 ha. If they own land at all, families in this area generally own some land of each type (average total land ownership is approximately 7 ha). Over 20% of the families interviewed own no land (Moroccan Livestock Service, 1986).

Review of local government records reveals that irrigated land holdings are small in Ain Beni Mathar (Table 3). Data on dryland was not readily available in this region because clear entitlement does not exist for the majority of lands, which, for the most part, have been claimed in the traditional manner.

A key factor in range use in Morocco is the transhumant nature of livestock production. At each of the sites studied, livestock grazing follows a seasonal pattern with herds moving from winter ranges to summer ranges and to crop residue. This system is quite rational, maximizing access to fresh forage while allowing areas to revegetate (Horowitz, 1979). However, increased herd pressure combined with the encroachment of crop production on what was previously communal land has placed this system under considerable stress. While one producer moves to a traditional summer range, another producer may remain with his livestock on the area, not allowing the vegetation an opportunity to recover.

THE TRANSHUMANT CROP/LIVESTOCK PRODUCTION SYSTEM

Agricultural production at the three sites is highly diversified and integrated. A schematic characterization of the various components and their relationship is presented as Fig. 2. Livestock production is the most important enterprise in the system, with crops providing some basic requirements for human and animal consumption. In spite of the secondary nature of crop production, the people should be considered as agropastoralists rather than purely pastoralists.

Crop Production

Two forms of crop production exist to a greater or lesser extent at each site: dryland and irrigated farming. Dryland agriculture is quite land extensive. Producer family holdings may exceed 25 ha; barley and wheat are the most commonly grown dryland crops.

Each site has some irrigated crop production. Although wheat or barley may be grown on these lands, other crops and uses are more common. This land is often devoted to production of alfalfa, corn, root and tuber crops (potatoes, carrots and turnips), fruit crops (apples and pears) and small gardens.

Fields are usually plowed using a wooden "roman plow" pulled by mules or donkeys. Animals are also used in harrowing the fields and in threshing. Some mechanized traction is used if the field is large and the producer has sufficient funds to rent or buy a tractor. Seed may be bought from government sources or on the local market or saved from previous harvests. About half of those interviewed use some fertilizer, although, based on the yields reported, there is some question as to whether or not the formulation or application rates used are appropriate. Neither herbicides nor pesticides are applied. Further, many do not weed their cereal crops because they consider these plants as forage for livestock to be grazed following harvest or during periods of fallow. Hand labor is often used to harvest a forage crop of weeds from cereal fields prior to grain harvest. This practice is common in cropland areas where forage for animals is in short supply during the period when crops are growing. The integrated crop and livestock production systems and the value of weeds as forage in Morocco have led agronomists working there to increase cereal production and to reconsider the benefits of weed control.

Average 1985 crop yields are presented in Table 4 for the three regions studied. Several interrelated factors account for these low yields. Drought was suggested by many producers as the cause; however, they readily admitted that drought conditions are generally more prevalent than favorable conditions. Another factor contributing to the problem is that much of the land being cultivated has very low inherent potential to produce crops due to limited soil-water availability and low soil fertility. An agronomist from the midwestern United States summed up his impression of the situation in Morocco by saying that 50% of the land cultivated for dryland cereals production produces only 10% of the crop. On irrigated land, limited irrigation water or excessive amounts of land under irrigation relative to the available water reduced yield to little better than dryland production in many cases. These factors, along with traditional farming practices (such as seeding after the first rains in the fall and planting by plowing the seed into the soil), ensure that yields will be relatively low by agronomic standards but may also ensure that there will not be total crop failure.

Livestock Production

Livestock production is the primary enterprise of producers in the semiarid zone. Four types of livestock are produced:

- small animals for food (chickens, turkeys and rabbits),
- cattle for milk and sale,
- equines (horses, mules and donkeys) for transportation and traction,
- small ruminants (sheep and goats) for sale and consumption of meat,
- wool, hides and dairy products,

Sheep and, to a lesser extent, goats are the most economically important livestock. The output from these animals is used directly by the family and sold to supply market goods. In the agropastoral system, the herd often serves as a capital reserve or "checking account on the hoof." While cattle and equines may graze solely on pastures or ranges near the home, sheep and goats are herded near and far.

Sheep are usually tended by an older son (though young girls or boys may tend a small flock near the home) or a hired herder. Though not a difficult job, herding requires the constant presence of at least one person to prevent animals from straying or being lost to predation.

The head of the household usually makes the major herd management decisions (such as sales and major herd movements) while the day-to-day management is up the herder. The herder usually follows a grazing pattern that may range as much as 10 km from the tent site. Major movements of the herd follow a seasonal pattern, using lowlands during the winter, moving to upper pastures in the spring and early summer, and returning to cropland to graze stubble during the late summer and early fall.

A major issue in range use is the concept of herding by association. In this arrangement, a person who may not have grazing rights will contract with a herder who has grazing rights. When the sheep are sold, the herder will receive a share of the lamb crop and some of the proceeds from the sale of sheep. The herder may also receive food and clothing as part of this arrangement. A similar arrangement may exist when a right-holding producer hires a herder, although employment of salaried herders is increasing.

Average herd size, herd structure and productivity for sheep and goat herds in the three regions of emphasis are presented in Table 5. The low productivity and high death loss in livestock herds are symptoms of a number of animal husbandry problems, the most basic of which is inadequate nutrition of animals. Although supplemental feeds are used to supply an average of almost 20% of the dry-matter requirements of animals across the study sites, ranging from 8% in the Timahdite areas to 30.3% in the El Faija area, nutritional requirements for reproduction and growth are not being met for many animals. For example, on-farm research results from the Timahdite area indicate that only 78% of the ewes that lambed in the 1984-1985 agricultural year had lambed again within 12 months, an additional 34% had lambed within 14 months, and after 18 months, an additional 5% had lambed. The fact that only half

of the known fertile ewes lambed on an annual basis is grounds for concern. These results were obtained with what producers viewed as some of their choice animals.

While inadequate nutrition was deemed the major problem, other factors contributed to low levels of production and production efficiency. A relatively large percentage of breeding animals were unproductive. Of 3,942 animals classified by wool quality and general suitability, 1,012 (25.7%) were assessed to be unfit or unproductive. Genetic and congenital abnormalities, advanced age, reproductive disorders (such as epididymitis in rams), acute symptoms of parasite infestation and disease were common.

Relatively simple but basic animal husbandry and management practices can correct these problems. However, the herd owner must become more involved in the day-to-day husbandry of the animals rather than leaving this responsibility solely to herders. Rapid improvement in production and production efficiency is possible through culling of inferior or defective animals, controlled breeding, management of feed and forage resources based on an understanding of animal nutrient requirement and effective parasite and disease control measures. Culling of unproductive animals results in higher levels of nutrition for the remaining animals and greater overall production in terms of lower death loss, more lambs and better animal condition.

Range Resources

Communal rangeland is the primary source of livestock, forage available to producers, though in some areas, state-owned forested rangelands are also available. Over the three regions represented in the study, rangelands provide from 45% to 85% of the total forage for the animals with the remainder provided from crops, crop residue and purchased feeds, depending on a producer's access to and the relative abundance of rangeland and cropland. In addition, fuel and building materials are gathered from the ranges. Wood is gathered for fuel where available, although sagebrush and alfa-grass provide fuel over much of the area. Removal of vegetation for use as fuel has become a major land degradation problem in some areas in recent years.

The primary method available for increasing forage production from communal rangelands is grazing management. While tribal members (rightholders) are organized on ethnic and political bases, the key to implementing grazing management is organization of rightholders to exert management control and to employ management techniques on communal rangelands. Formation of cooperative herds and development of specific herding patterns have been shown to be appropriate management techniques on communal rangelands in Morocco. With cooperative herds, many of the animal husbandry and management practices impractical for small herds become feasible. This approach has been demonstrated by the Moroccan Livestock Service and local producers in the Ain Beni Mathar area where tribal organization and leadership is relatively strong.

On some rangelands other forms of range management involving manipulation of vegetation and soils are viable alternatives for

increasing forage production. The Moroccan Livestock Service has successfully employed range seeding with introduced species (primarily Agropyron spp.) on selected communal rangelands since the early 1970s. The search for forage species adapted to semiarid Moroccan rangelands continues, and the emphasis is turning toward endemic species for their grazing tolerance and known adaptability to local environments.

Project staff initiated demonstrations and research trials on a variety of technologies including contour furrowing and terracing, shrub planting and seeding, both separately and in combination. All show promise for increasing forage production and reducing runoff and associated soil erosion in both the sagebrush and alfa-grass vegetation types that dominate these semiarid regions. Establishment of large scale shrub plantations, a program initiated by project staff near the rural community of Ain Beni Mathar, also demonstrated the potential to provide a much-needed local source of fuelwood in addition to livestock forage.

The Family Unit

A household is rather difficult to define because a homestead may include a number of related nuclear families whose quarters are not distinct. Further, there is often, though not always, sharing of resources, particularly in the case of inherited croplands. In this study, producers defined the household, which was generally that group headed by one given adult. These households varied in size from 2 to 18 family members with an average of 8.

The Division of Labor

Labor appears to be clearly divided by age and sex. Most family members over 7 years old have some type of chore. Young children may tend animals close to the home, care for younger children and fetch water. Women and older girls are primarily responsible for housekeeping activities, including gathering fuelwood and hauling water. The women will assist in the harvest, particularly in Berber areas. Women also tend the small and sick animals as well as milk the goats, sheep and cattle. Herd management activities such as herding, shearing, sales and slaughter are primarily male tasks.

The family may engage in a number of nonfarm enterprises. One of the most common is the weaving of rugs, cloth, mats and baskets by women. Off-farm labor is also common. Often a male household member will work for another producer or some other employer such as the government as day labor. Family members may also go to one of the large cities in Morocco or Europe to work. Though it has proven nearly impossible to measure, this activity provides important revenue to the household. The issue of how this income is used once it enters the household was not specifically addressed; however, based on household demand for cash derived from estimates of income and expenditures, it appears to enter a common pool.

The activities that demand the greatest input of labor to the household are domestic tasks. Labor use in person-days for small producers in the

El Faija area is presented in Table 6. Domestic activities of women and girls take up to 80 person-days per month throughout the year. Peak periods of labor demand for agricultural activities occur during April when major maintenance on livestock facilities takes place. More significant are the harvest activities during June and July and planting during October and November. These periods of high labor demand are similar for producers at the other two sites.

In some cases, particularly among producers with relatively large holdings, these peak demands for crop production are often satisfied through contracting for labor outside of the family. Laborers may be paid a straight salary ranging from 17 to 22.5 Moroccan Dirhams (DH) per day, or they may enter into an annual agreement called "khammes" or "one-fifth" whereby the laborer receives one-fifth of the harvest for the work performed.

The Market

The vast majority of producers are integrated into the market. Animals are sold on a per-head basis; however, buyers place a great deal of emphasis on animal size and condition since meat is marketed on a weight basis. Each major town has a weekly market of "souk" that provides food and supplies that are not produced by the household. The purchase of supplemental feeds (such as barley, bran and sugarbeet pellets) represents a major expenditure.

The souk provides the avenue for the sale and purchase of livestock and sale of surplus crop or small animal production. Sheep are sold throughout the year as the need for cash arises. This type of sale is particularly evident before planting or when labor must be hired. In addition, sales of animals increase when the lambs are weaned and preceding major holidays or feasts. When there is excess cash, it will often be reinvested in sheep. When cash is needed for major expenses such as the purchase of fertilizer, it is often raised through the sale of animals. Some speculative trading occurs whereby an individual will purchase a few sheep for fattening on the expectation that the price will rise over the next few weeks.

Livestock and crop prices in Morocco are relatively high, but, as previously discussed, production and production efficiency are low. High prices for barley, harvested forages and commercial feed supplements translate directly to high livestock production costs since there is relatively high dependence on these nutrient sources for meeting livestock requirements.

ECONOMIC ANALYSIS OF PRODUCTION SYSTEMS

Partial budgeting and budgeting were used in the economic analyses of production systems. Partial budgeting was used to estimate the effects of various technical and operational alternatives such as range seeding, restructuring livestock herds and grazing management on the production systems. Budgeting was used in evaluating the combination of production

activities included in the production systems as a whole by estimating the cumulative effect of a production strategy.

Conceptual models of the production systems based on estimates of production parameters, costs of resources used in production and prices of products of the production processes were developed from on-farm research data. These models served as an aid in integrating biological and socioeconomic information to estimate the value of production system activities. To aid in organizing information and in computations, as well as to allow consistent treatment and reporting of information, a microcomputer application called PROMO (Banner and Bartel, 1986) was developed for use with a readily available spreadsheet program.

Estimates of some economic parameters of crop/livestock production systems are presented by region in Table 7. This information shows that livestock production costs are relatively high. Most of these costs are related to feed and forage. Average feed and forage costs per mature ewe range from 6.4 DH/month in Ain Beni Mathar to 10.57 Dh/month in Timahdite to 12.1 DH/month in El Faija. These costs rise as the degree of dependence on nonrange sources of forage for livestock production increases. While a high potential exists for increasing net returns to producers by increasing crop and livestock production and production efficiency through improved management, a great deal can be done to reduce livestock production costs (feed and forage costs) by increasing forage production on communal rangelands.

While the Moroccan government is proceeding with cooperative development efforts on communal rangelands and individual producers are known to have adopted improved animal husbandry practices as a result of participation in project programs, the short-term nature of this project effectively precluded the monitoring necessary to evaluate the degree to which interventions proved to be useful to target groups and were adopted. However, potential net returns to producers are estimated to be increased by as much as threefold if improved range and livestock management technology is adopted. To realize these benefits, both individual and group commitment from producers is required.

TECHNOLOGY TRANSFER

Historically, management and improvement of collectively owned resources, such as rangelands, have proven difficult. Success of most range management practices is largely dependent on control of rangeland use. Being aware of this, project technicians approached range management extension and improvement programs in Morocco based on three precepts:

- Producers must recognize problems and desire assistance.

- Technical interventions must produce results that quickly alleviate producers' problems.

- Improved management and development of communal rangelands requires that producers act as organized groups of participants that control range use.

The recognition of immediate and serious problems in basic animal husbandry prompted initiation of a program of producer field days around Morocco for improving livestock, management (such as animal selection and culling, management of feed and forage resources based on animal requirements, effective animal health care), an area of high individual producer interest and feasibility. The field days were patterned after Livestock Service animal health campaigns that were well known to producers. In addition to those on the project staff, approximately 10 Livestock Service technicians were involved in the program, receiving training and later interfacing with producers. Producer interest in improving animal husbandry was high as indicated by very high participation in the field days in spite of the fact that, unlike health and feed campaigns where vaccinations are administered with no charge or where feed supplements are distributed at no cost to producers, nothing was being given away but technical advice and information.

Over the last year of the project, field days were held in seven locations around Morocco. Approximately 150 livestock producers participated, and 4,600 sheep were evaluated. Most of these producers quickly grasped the concepts and procedures involved in the evaluation process and became actively involved in the review of their animals. Early in the program, field days were held in locations where project activities were on-going, and later the program was introduced into new areas. The rationale for this extension program was to introduce effective techniques that produce quick, beneficial results to producers (increased production efficiency and reduced costs) and that build awareness, interest and commitment among producers for improving management of their animals and communal rangelands. Programs that result in rapid improvement build credibility for extension agents and extension programs, thereby improving producer receptivity for interventions that require higher levels of commitment as individuals and as a group, greater resources and longer timeframes to produce results.

In taking this approach, technicians introduced discrete practices (selection of desirable animals, removal of nonproductive animals and management of animals by class) to individuals and groups of producers that resulted in a decrease in costs and an increase in efficiency. These practices were all effective when applied separately and complementary when applied in combination. In this way, basic animal husbandry practices, some of which were not sensitive to herd size, were introduced. The program goal was to build on these practices until organized groups of producers were requesting assistance with large-scale range and livestock development programs. Much effort was spent in helping motivated producers organize themselves into functional management groups that could reach consensus, participate in development responsibilities and employ range and livestock management techniques not feasible for individual producers.

SUMMARY

Project personnel from the Moroccan Livestock. Service and Utah State University adopted a three-part strategy for improving the welfare of Moroccan agropastoralists dependent on communal rangelands. The three components of the strategy were to

- collect as much information as possible on structure, operation and output of the crop/livestock production systems and thereby increase our recognition and understanding of existing problems,

- identify and quantify the expected benefits that could be derived from alternative range and livestock management practices,

- develop strategies and programs for transfer of this technology to individuals and groups.

On-farm research provided quantitative information on livestock production and range management practices that allowed technicians to plan and implement effective extension programs. Since producers with relatively small landholdings and livestock herds were limited in what kinds of technology they could adopt, emphasis was placed on extension programs to improve basic animal husbandry based on several discrete livestock management practices, some of which required nothing more of the producer than attention to individual animals.

The need for increasing forage production from communal rangelands was critical for all producers, but, because it required organized use and management, it was not feasible unless producers organized themselves as a group to control range use and to participate in management of their rangelands. Project personnel devoted much of their effort to assisting producers in forming organizations capable of managing their communal rangeland.

The keys to the success of this program were

- recognition of problems important to producers,

- development of numerous alternatives for addressing these problems, some of which were appropriate for all producers regardless of scale,

- formation of producer organizations for addressing large-scale common problems.

Rather than trying to develop a total package of technical interventions and hoping to be able to transfer it, emphasis was placed on development
of a set of interventions that provided some practices that were appropriate for any producer.

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Table 1. Characteristics of the biological and physical environment at three research sites in Morocco.

Characteristic	Location		
	Timahdite	El Faija	Ain Beni Mathar
Elevation	1800-2400 m	1600-1800 m	1000-1600 m
Soil derivation	Basalt and limestone	Sandstone and marine shales	Sandstone and marine shales
Vegetation types	Forest/shrub	Shrub	Shrub
Avg. annual ppt.	400 mm	300 mm	200 mm
Avg. monthly temp.	0°C-25°C	5°C-25°C	5°C-25°C

Table 2. Distribution of cropland among landowners in Timahdite, Morocco.

	Cropland Class					
	Dry cropland			Irrigated cropland		
Size class (ha)	Total area (ha)	Percent of area (%)	Percent of pop. (%)	Total area (ha)	Percent of area (%)	Percent of pop (%)
0-4.9	647	10.31	72.03	732	8.24	61.76
5-9.9	924	14.73	11.55	1204	13.55	15.23
10-29.9	2422	38.60	12.75	3586	40.37	17.45
30-39.9	658	10.49	1.63	908	10.22	2.22
40+	1623	25.87	2.04	2452	27.62	3.34
Total	6274	100.00	100.00	8882	100.00	100.00

Table 3. Distribution of irrigated cropland among landowners in Ain Beni Mathar, Morocco.

Size class (ha)	Total area (ha)	Percent of Total area (%)	Landowner population (%)
0-0.25	2.32	1.19	69.28
0.26-1.00	17.27	8.86	10.25
1.1-2.00	35.17	18.05	8.54
2.1-4.00	67.49	34.63	7.86
4.1+	72.62	37.27	4.07
Total	194.87	100.00	100.00

Table 4. Average Yield[1] rates of crops at three research sites in Morocco.

	Crop yield rate by location and land class					
	Timahdite		El Faija		Ain Beni Mathar	
Crop	Irrig. (kg/ha)	Dry[2] (kg/ha)	Irrig. (kg/ha)	Dry[3] (kg/ha)	Irrig. (kg/ha)	Dry[3] (kg/ha)
Wheat	420	100	500		900	
Barley	380	230	430		800	400[4]
Corn	270		370			
Oats	370	400				
Vegetables (misc.)	_ _5		630		_ 5	
Potatoes	2550					
Alfalfa			700		3200	
Apples			2100			

[1]Yields reported by producers cooperating in on-farm research averaged by crop and research site.
[2]Dryland crops were not planted by some producers due to dry
[3]Dryland crops were not planted in the region due to dry conditions.
[4]Some fields were grazed rather than harvested for grain due to low yields.
[5]Although vegetables were grown in small plots, yield was not reported.

Table 5. Estimates of average herd size, structure and production for sheep and goat herds at three research sites in Morocco.

Production parameter	Timahdite	El Faija	Ain Beni Mathar
Sheep herd information			
# of mature females	271	104	156
Size range of herds	60-580	25-240	120-223
Breeding males:females	1:29	1:27	1:36
Female replacement rate	1:4.3	1:6	1:5.7
Lamb crop[1] (%)	61.4	46.3	56.8
Adult death loss (%)	6	12	8.4
Goat herd information[2]			
# of females	67	30	22
Size range of herds	4-130	17-42	16-28
Breeding males : females	1:36	1:18.5	1:10.2
Female replacement rate	1:5	1:7	1:4.9
Kid crop (%)	60.2	40.6	57
Adult death loss (%)	6	14.2	7.5

[1]Percentage of lamb crop or kid crop was defined as the number of offspring raised to weaning or market age per breeding female per year.
[2]Approximately 25(%) of the cooperating producers raised goats. Values presented are averages for only those producers raising goats.

Table 6. Estimated labor use in person-days by season for small producers near El Faija Grazing Perimeter.

Activity	Seasonal[1] labor use in person-days				
	Winter	Spring	Summer	Fall	Total
Livestock production					
Herding — range	70	105	80	100	355
Herding — crop residue			40	20	60
Feeding	15	5		5	25
Shearing		1.3			1.3
Lambing	5.1			1.6	6.7
Corral/barn cleaning		16.7			16.7
Corral/barn repair		5			5
Animal health care		1.3		1.3	2.6
Small animal husbandry	15	15	15	15	60
Crop production					
Plowing and seeding			7.7	9.4	17.1
Irrigation			5.4	7.7	13.1
Fertilization			5.4	2.7	8.1
Harvest			15	13	28
Threshing			10	10	20
Transportation			8	10	18
Marketing	3.9	9.3	6.6	3.9	23.7
Domestic activities	240	240	240	240	960
Total	349	398.6	433.1	439.6	1620.3

[1]Seasons are defined as follows:
Winter = December - February
Spring = March - May
Summer = June - August
Fall = September - November

Table 7. Estimates of costs, returns and percentage returns for crop/livestock production system in three semiarid regions of Morocco.

Parameter	Timahdite (means)	El Faija (means)	Ain Beni Mathar (means)
Livestock revenue (DH)	71,570	30,666	30,387
Livestock costs (DH)	62,399	43,679	25,274
Livestock net revenue (DH)	9,171	<13,013>	5,113
Net revenue/costs (%)	14.7	<29.8>	20.2
	31,102	12,613	27,558
Crop revenue[1] (DH)	12,007	4,972	12,667
Crop costs (DH)	19,095	7,641	14,891
Crop net revenue (DH)	159	153.7	117.6
Net revenue/costs (%)			
Revenue derived from other sources[2] (DH)	—	1,197	101
Production system net revenue (DH)	28,266	<4,175>	20,105
Resource inventory value[3] (DH)	687,847	264,933	233,351
Percent return on resource inventory	4.1	<1.6>	8.6

[1]Crops are generally used to support the livestock production activity. Crop returns were estimated based on their market value less transportation costs.
[2]Net revenue from other sources included wages from outside employment, military pensions and revenue from family members living away from the family. These estimates are recognized as incomplete.
[3]Resource inventory value is the value of land, livestock and equipment used for production.

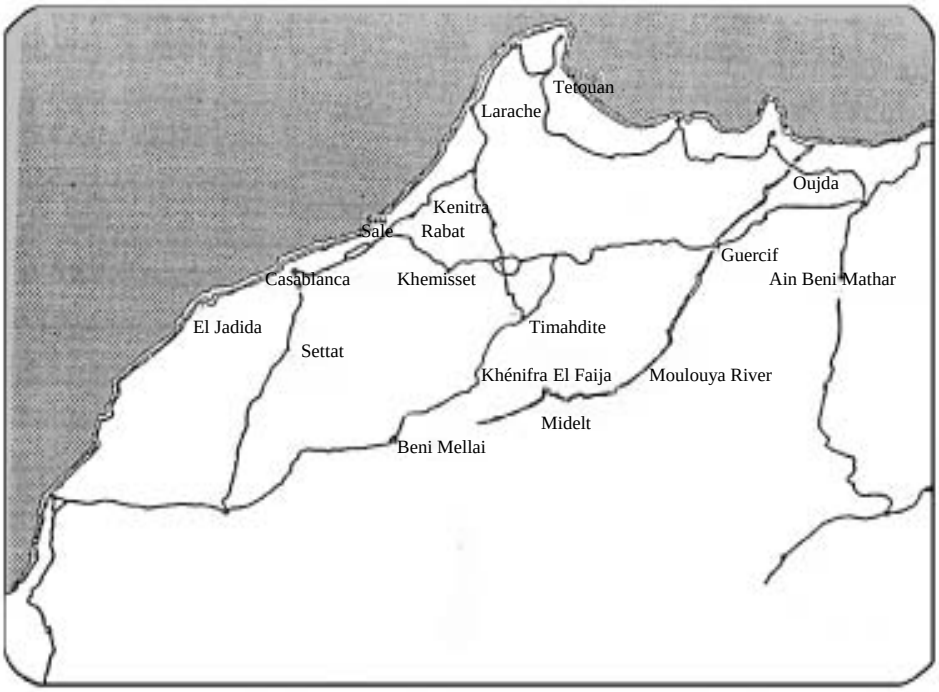

Fig. 1. Map of northern Morocco with approximate locations of research sites at Timahdite, El Faija and Ain Beni Mathar indicated (*).

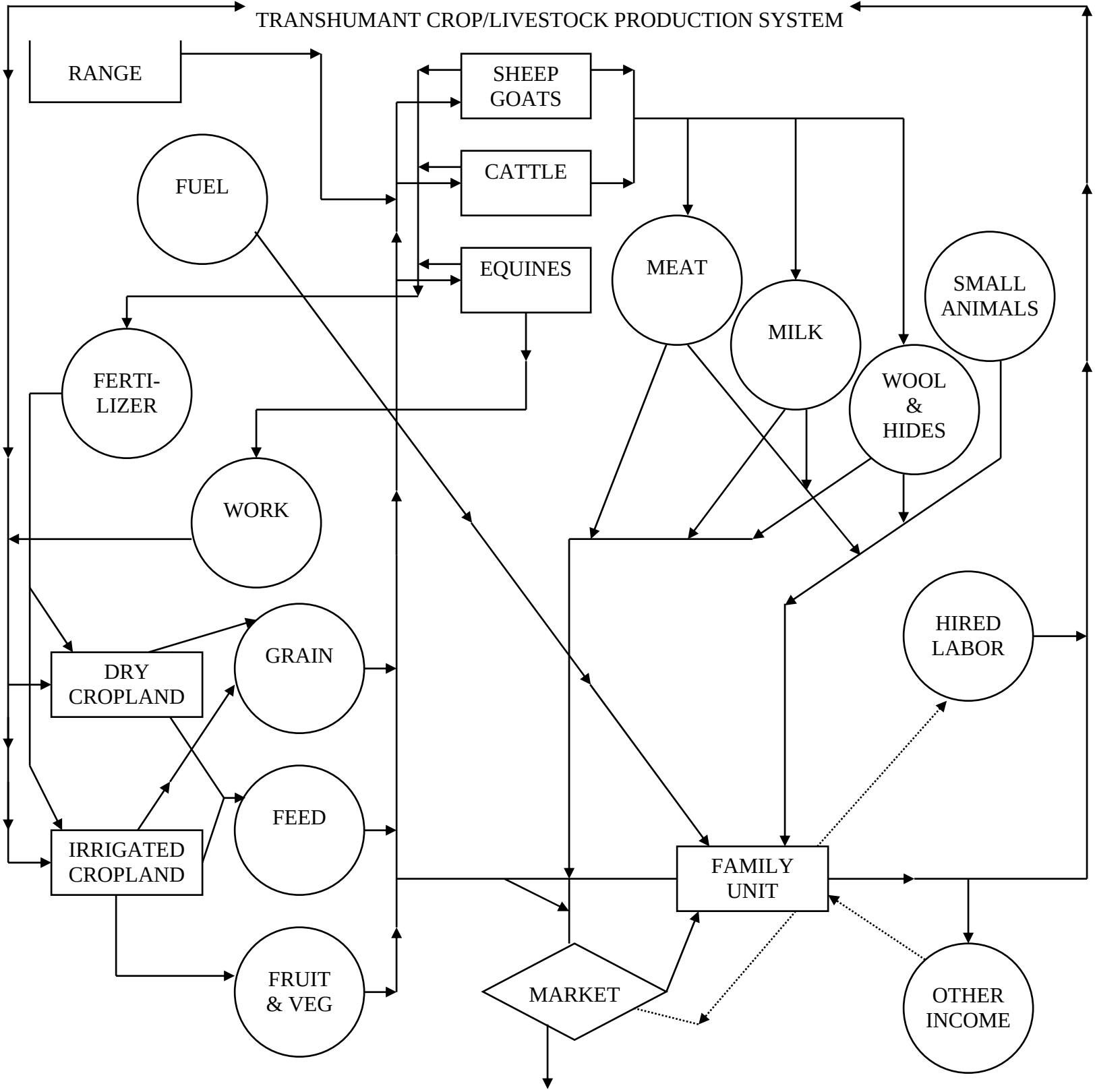

Fig 2. A general model of transhumant crop/livestock production systems in semiarid regions of Morocco.

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SHEEP PRODUCTION FROM INTEGRATING LIMITED INTENSIVE PASTURES WITH RANGELAND IN SOUTH AFRICA

David I. Bransby and T. M. Du Plessis[1]

INTRODUCTION

The province of Natal is situated in the eastern part of South Africa, extending from the coast up to the eastern escarpment, which exceeds an altitude of 3,000 m in places. Immediately below the escarpment (1,400m to 1,950 m) lies the highland region, which constitutes 21% of the province. Topography varies from rolling to mountainous, with limited area of land available for tillage. Annual precipitation varies between 800 mm and 1,300 mm, with a median of about 970 mm. The rain occurs mainly in the summer, when hailstorms constitute a serious hazard for row-crop farmers. Maximum temperatures reach 35°C, while severe frosts and occasional snow are associated with minimum temperatures below -10°C in the winter.

Soils of these highlands are typically acid with high levels of aluminum and a severe deficiency of phosphorus (P). The soil-erosion hazard, however, is low because most of the area is dense native grassland that is relatively stable. This perennial grassland is maintained by fire and grazing. It is palatable and nutritious to livestock during the summer, but very low in quality during the winter. However, due to heavy stocking and poor grazing management, the palatable grass species, such as *Themeda triandra* and its associates, are steadily being replaced by less nutritious plants. The carrying capacity and nutritive value of the natural grassland are, therefore, decreasing. Agricultural activities in the region are strongly oriented toward livestock production; wool sheep are the most important followed by beef cattle, with intensive fat lamb and dairy production playing a relatively minor role. Production systems have traditionally been extensive, relying heavily on the natural grassland and making only limited use of crop residues and planted pastures. The region has good supplies of surface water, but these remain largely untapped for irrigation.

Farms in the highlands of Natal average just over 800 ha, but many are under 500 ha. Such units are considered to be marginal to subeconomic under current extensive wool- and beef-farming systems. This contention is supported by mail-in records that indicate that annual net farm income for 70% of the farms in the region was less than R6,000 (Berry and Whitehead, 1979). (R = rand, South African currency currently valued at US$0.50. In South Africa, it has a similar buying power to that of the U.S. dollar in the United States.) Furthermore, no additional employment opportunities exist for the farm community, which relies almost entirely on income generated from farming.

This study was aimed at developing a more profitable alternative for farmers who currently employ extensive livestock-farming practices in the highlands of Natal. Our specific objective was to test the

[1]Department of Agronomy and Soils, Auburn University; Department of Agriculture, Cedara, Natal, South Africa.

feasibility of integrating intensive irrigated pastures with rangeland for fat lamb production under both research and farm conditions. This was to be done by developing and testing a first-approximation model describing the system. Due to high infestations of internal parasites associated with spring lambing and corresponding high lamb mortality, lambing in the region takes place predominantly in late summer (March). This coincides with a severe drop in forage quality of the natural grassland and the onset of the dry winter months. Irrigated, high-quality, cool-season pastures would, therefore, be required for fat lamb production. Without these pastures (or alternately, very expensive supplemental feeding) lambs would not reach slaughter weight by December, when prices are traditionally high. Furthermore, on natural grassland, even in the spring and summer, the condition of lambs would not be adequate to achieve top grades, thus resulting in further economic loss. However, information gathered informally by the extension service suggested that wool farmers were doubtful that sheep could be carried at an adequate stocking rate and gain at a high enough rate to economically justify expensive irrigated pastures. In particular, the extremely cold midwinter months of June, July and August were of concern because low night temperatures severely restricted pasture growth during this period.

Additional information that was required included the most appropriate pasture species or species mixture and optimum levels of nitrogen (N) fertilization. Traditionally, irrigated winter pastures consisted only of annual ryegrass (Lolium multiflorum). They were used almost entirely by dairy farmers who were reluctant to include a legume in their pastures because they were not willing to run the risk of bloat. Consequently, levels of N fertilization on ryegrass pastures often exceeded 300 kg N/ha on farms, and forage quality deteriorated rapidly in early summer at the onset of reproductive growth. From both a fertilization and forage quality standpoint, therefore, it seemed advantageous to include a legume with ryegrass, provided low risk of bloat could be demonstrated. Finally, the possible benefits of multiple births needed to be investigated. This was necessary because of prejudice among some wool farmers against multiple births as a result of very high mortality rates for twin lambs under extensive rangeland conditions.

THE RESEARCH

In developing a research strategy, every effort had to be made to achieve credibility among target users, thus increasing the potential for adoption of the system if it proved successful. Since there was no research station within easy access of the target community, the research was conducted on a small farm that belonged to the junior author and that was well located in this regard. Small-plot studies starting in 1981 showed that a mixture of annual ryegrass with Kenland red clover (Trifolium pratense) and Ladino white clover (Trifolium repens) provided higher yields than did annual ryegrass alone or in combination with a number of other legumes. In addition, under small-plot conditions there appeared to be very little response to N fertilization above 175 kg N/ha. Subsequent stocking-rate grazing

trials confirmed that 1) a mixture of annual ryegrass with red and white clover could sustain a higher stocking rate than could ryegrass alone, and 2) under grazing there was no response to N fertilization of the ryegrass-clover mixture above 275 kg N/ha.

The grazing study continued for 3 years. Each year yielded similar results, but it was only in the third year that an adequate proportion of twins were born to allow twins to be represented at all stocking rates in the trial. Consequently, the model developed in this study was based only on data from the third year. While it is recognized that this was not an ideal procedure, the relatively small variation from year to year for single lambs (probably due to the control afforded by irrigation) suggested that it would suffice as a first approximation.

Site and Climate

The research site was situated 15 km west of Underberg in Natal (29°E and 30°S). It was almost level (3% slope), and the soil was classified as a Hutton form (MacVicar et al., 1977), which is well drained, highly leached and mostly deeper than 900 mm. The soil pH was 4.3 in KC1, but due to previous liming, the soil contained low levels of free aluminum. Over a 20-year period, the mean annual rainfall was 1,025 mm, with only 80 mm occurring between May 1 and September 30. Mean daily temperature per month varied from 7.7°C in July to 17.3°C in January. Although winter days are warm (20°C), severe frosts occur for 100 to 120 days in midwinter.

Experimental Procedure

The 2-ha trial site was fertilized with P and potassium (K) according to soil tests following initial plowing in early February. Thereafter, a fine seedbed was prepared, and annual ryegrass, red clover and white clover were seeded by broadcasting seed and cultipacking, using 15 kg, 8 kg and 3 kg of seed/ha, respectively. Supplementary irrigation was applied to ensure that the pasture received 25 mm every 10 days.

In March, 55 pregnant Corriedale ewes were purchased. Following lambing in April, 42 ewes with their lambs were blocked according to lambing date and multiple births, one-third of the ewes having borne twins. Sheep within each block were randomly allocated to one of the following seven nonreplicated stocking rates: 16, 20, 24, 28, 32, 36 and 40 ewes plus their lambs/ha. Grazing started in the first week of May (with lambs weighing, on average, 3.6 kg) and continued until the lightest group of lambs weighed 18 kg. At this time lambs were weaned and ewes were turned out onto rangeland. However, with all the twins, there were 53 lambs/ha in the paddock that was initially stocked at 40 ewes/ha. Results from previous years indicated that this stocking rate would probably not be sustainable through midwinter. Consequently, lamb numbers were reduced following weaning. Lambs were subsequently blocked according to weight and multiple births and randomly reallocated to paddocks so that the lamb stocking rates were the same as the previous stocking rate of ewes/ha.

Ewes and lambs were weighed every 7 to 14 days during the trial period and dosed for internal parasites at 21-day intervals. When lambs reached 40 kg, they were marketed to the abattoir. Separate linear regressions between average daily gain (ADG) and stocking rate were established for single and twin lambs before weaning and for all lambs together from weaning until slaughter weight was attained. These functions were subsequently used to develop a model for determining the length of time required for lambs to attain a slaughter weight of 40 kg, with stocking rate, weaning weight and proportion of twins as explanatory variables. This model was then expanded to include economic variables.

RESULTS

Relationships between ADG and stocking rate for lambs are well described by linear functions, with correlation coefficients (r) ranging from -0.81 to -0.98 (Fig. 1). These data are in agreement with results from many other stocking-rate studies (Riewe, 1961; Riewe et al., 1963; Cowlishaw, 1969; Hart, 1972; Jones and Sandland, 1974; Hart, 1978; Bransby, 1984; Smith et al., 1986a and 1986b).

However, this study differed from others in that the postweaning ADG for lambs was determined from different length periods for each stocking rate because grazing continued until a slaughter weight of 40 kg was attained. While such a procedure might have had limited value from an experimental point of view, for the purpose of model development it was more appropriate than grazing all stocking rates for the same period of time.

There was no significant difference between regression coefficients for single and twin lambs after weaning. These data were, therefore, pooled to obtain a common regression between ADG and stocking rate for all lambs from weaning until slaughter weight was attained. The regression coefficients for single and twin lambs before weaning and for all lambs after weaning were not significantly different, but when a common slope was adopted for all three lines, the difference among the intercepts was significant (P=0.01). However, in order to attain maximum precision in the model, independent slopes were retained for each regression.

On average, the ADG of lambs before weaning was considerably higher than that after weaning; for single lambs this difference was 179 g/day. Consequently, delaying weaning was a strategy that would reduce the time required to attain slaughter weight. However, it would lengthen the preweaning period, thus necessitating retention of ewes on pasture further into the reduced-growth winter period. Weaning weight was, therefore, included as a variable in the model. Due to the difference in ADG between single and twin lambs before weaning, the proportion of multiple births would also affect the amount of time required to attain slaughter weight, but to a lesser extent. However, multiple births have a distinct effect on gross margin per ewe, and for this reason the proportion of twins was also included as a variable in the model.

THE MODEL

The purpose of the model described in this study was to develop the most profitable fat-lamb-production system that was logistically feasible, with stocking rate, weaning weight and proportion of twins as input variables. Due to the high lamb prices commonly found immediately prior to the Christmas holiday period, December 15 was chosen as the target marketing date. The target slaughter weight was 40 kg, since this corresponded with 18-kg to 20-kg carcasses that usually graded well. Another important constraint was the low forage production that was associated with low midwinter temperatures. Consequently, it would be necessary to wean lambs and remove ewes from the ryegrass-clover pastures no later than mid-June.

Since ADG for single lambs up to weaning (ADG_S) was related to stocking rate of ewes (S) by the equation $ADG_S = 432-3.76S$ (Fig. 1), the number of days from birth to weaning (T_1) could be determined as follows:

$$T_l = (w_w - W_b)/(432-3.76S)$$

where

W_w = represents the weaning weight
W_b = the birth weight, expressed in grams.

In this study the birth weight was assumed to be 1.5 kg. Since the average weight of lambs at the start of the grazing experiment was 3.6 kg, this represented extrapolation slightly beyond the limits of experimental data.

For weaning weights between 18 kg and 26 kg and stocking rates between 16 and 40 ewes/ha, the estimated time from birth to weaning ranged from 44 to 87 days (Table 1). The length of this preweaning period increased with weaning weight because more time was required to attain higher weaning weights, and increased as stocking rate increased because of the corresponding decrease in gains. Since the appropriate date for the start of grazing was considered to be April 1, and it was important to wean by June 15, all combinations of weaning weight and stocking rate that resulted in estimated preweaning periods of 76 days or less would be feasible. This excluded just a small proportion of the options presented in Table 1.

The ADG of twin lambs prior to weaning (ADG_t) was expressed in terms of ewe stocking rate by the following equation:

$$ADG_t = 354 - 2.43S.$$

If the proportion of ewes that bore twins is represented by $_t$, then the number of twin lambs would be $N2_t$ and the number of single lambs would be $N(l- _t)$, where N is the number of ewes. In addition, where the lamb

crop contained twins, the estimated ADG for all lambs (ADG_a) could be determined by the following equation:

$$ADG_a = ADG_S\ (1 - {}_t) + ADG_t\ (2\ {}_t).$$

Consequently, the lower ADG of twin lambs before weaning and the proportion of twins could also be considered in estimating the number of days from birth to weaning. However, the proportion of twins had a relatively small effect on the length of the preweaning period, despite single lambs gaining, on average, 41 g/day more than did twin lambs. For example, assuming that 33% of ewes had twins (i.e., half the lambs were twins), for a stocking rate of 40 ewes/ha and weaning weights of 18 kg and 26 kg, the expected length of the preweaning period was 61 and 91 days, respectively. This represented a corresponding increase in the preweaning period of only 2 and 4 days over the case in which only single lambs were assumed (Table 1).

The ADG for all lambs in the postweaning period (ADGp) was related to lamb stocking rate (S_a) by the following equation:

$$ADGp = 224 - 2.71S_a.$$

Consequently, the number of days in the postweaning period (T2) was determined by dividing the difference between 40 kg (slaughter weight) and the weaning weight by ADG_p, and the total time required from birth until marketing was provided by the sum of the pre- and postweaning periods.

If only single births were assumed, the expected total time required from birth until marketing ranged from 143 to 250 days, depending on stocking rate and weaning weight (Table 2). Adjusting weaning weight from 18 kg to 26 kg increased this period by 23 days for a stocking rate of 16 ewes/ha and by 41 days at a stocking rate of 40 ewes/ha. In addition, an increase in initial stocking rate from 16 ewes/ha to 40 ewes/ha increased the period by 84 days for a weaning weight of 18 kg and by 66 days for a weaning weight of 26 kg. Since the period from April 1 to December 15 consisted of 259 days, all possibilities represented in Table 2 appeared to be feasible, except those subject to the weaning-date constraint already mentioned.

ECONOMICS

Experience with dual-purpose sheep (such as Corriedales) on rangeland in the highlands of Natal has demonstrated that income derived from wool will at least cover the costs of maintaining ewes. Consequently, this was assumed for the purpose of this study, and only the intensive, irrigated pasture phase of production was considered in the following economic assessment.

Expenditure

Total expenditure can be divided into two main components: pasture costs such as fertilizer, establishment and irrigation costs and animal

costs that include the expenses directly associated with keeping animals, such as veterinary and marketing costs. Pasture costs were made up as follows, based on figures obtained in November/December 1985:

	Rand/ha
Land preparation and planting	91.62
500 kg superphosphate/ha	118.09
275 kg N/ha @ R 1.15/kg	316.25
30 kg ryegrass seed	65.00
4 kg red clover seed	40.00
3 kg white clover seed	52.00
Irrigation	34.29
Total	717.25

Animal costs were made up of veterinary, labor and marketing costs. Veterinary costs were 0.88 c/day for ewes and 1.00 c/day for lambs. The higher cost for lambs was related to the necessity to administer a tapeworm remedy in addition to the broad spectrum remedy that was provided for ewes. Based on the average for the highland region, labor costs were assumed to be 0.83 c/lamb/day, and marketing costs were made up as follows:

	Rand/lamb
Abattoir fee	3.00
Slaughter fee	0.60
Levies	1.20
Agents fee	2.40
Insurance	0.64
Transport	1.90
Total	9.74

Total expenditure/hectare could therefore be calculated by adding pasture costs/hectare to animal costs/hectare, which were determined by stocking rate, weaning weight, length of pre- and postweaning periods and proportion of twins.

Income and Profit

Since lambs on all stocking rates were retained until they reached 40 kg, gain and income were simply linear functions of stocking rate, and profit was determined by subtracting expenditure. The effects of weaning weight and proportion of twins on the per unit area economic data were negligible and are therefore not discussed. Assuming a weaning weight of 18 kg, expenditure rose by R384/ha as stocking rate was increased from 16 to 40 lambs/ha (Table 3). Furthermore, assuming the average lamb price for December 1985 of R2.00/kg live weight, the corresponding increase in income and profit/hectare were Rl,920 and Rl,536. This analysis clearly differs from other published economic analyses of stocking rate data (Bransby, 1985; Hildreth and Riewe, 1963; Riewe, 1981) in that profit did not reach a maximum within the range of

the data. On the other hand, profit/ewe was asymptotic in nature and increased almost directly with the proportion of twins born (Fig. 2). Assuming only single lambs and a stocking rate of 40 ewes/ha, expected profit/ewe was R47, and if 33% of ewes bore twins, this increased to R64, thus representing a decided advantage over wool sheep for which the average gross margin was R21/head on local farms.

A significant observation on the grazing trial was that from mid-September all paddocks (including the 40 ewes or lambs/ha stocking rate) were underutilized. This represented opportunity for flexibility in the system and for increased efficiency and profit. Also of importance was the fact that ryegrass ceased growth in November, but the clover provided an extended grazing season through December and into January.

FARM EVALUATION

The system developed in this study was tested on a nearby farm in 1985, with certain minor deviations. An area of 5.6 ha was used for the test pasture. The soil was a Clovelly form (MacVicar et al., 1977), which had properties similar to that at the experimental site. Irrigation was applied in the same pattern as for the experiment, but N fertilization was higher: N was applied at 63, 37, 89, 92 and 36 kg/ha in March, April, May, August and September, respectively. This modification was made because a lower proportion of clover was achieved compared to the grazing trial. The pasture was grazed by 180 Mutton Merino x Corriedale x Ille de France crossbred ewes and lambs, starting on April 3. This represented a stocking rate of 32 ewes/ha, a conservative choice (relative to the 40 ewes/ha achieved in the grazing trial) made by the producer. Lambs were weaned at an average weight of 18 kg on June 3. This was a 61-day preweaning period and represented a corresponding lamb ADG of 271 g, compared to the predicted values of 53 days (Table 1) and 311 g/day.

All lambs were not marketed simultaneously, but on average, all 180 lambs took 186 days to reach a mean market weight of 40.1 kg, thus representing a mean ADG of 208 g from birth to slaughter and an average market date of October 6. The corresponding predicted values were 214 days from birth to slaughter (Table 2), a mean ADG of 180 g and an average market date of November 3. Consequently, although the model overestimated ADG for the preweaning period, it underestimated for the postweaning period. This may have been due to the different breeds of sheep used on the farm and in the research.

At the time of marketing the lambs, pasture growth was extremely rapid. This enabled the producer to graze additional lambs (which had been born later in the winter and which had been grazed inferior pasture) until November 20 when grazing was terminated due to a shortage of clover in the pasture and inadequate irrigation. Grazing was applied on a put-and-take basis during this time, with batches of lambs being marketed as they reached 40 kg. On average, the pasture was stocked at 76 lambs/ha for this 45-day period, and 781 kg/ha were produced, thus representing an ADG of 228 g.

Due to the higher P and K levels required by the producer and the higher N fertilization applied, pasture cost was Rl,004/ha, R287/ha higher than that determined for the grazing trial. Veterinary, labor and marketing costs were R451/ha, bringing total costs to Rl,455/ha. Considering only the first 180 lambs marketed from the 5.6-ha pasture, income and profit were R2,566 and Rl,lll/ha, respectively. Increased pasture costs, therefore, resulted in a profit that was 20% below that predicted (Table 3).

In order to carry the second group of 76 lambs/ha for 45 days, a further application of 75 kg N/ha was necessary, and this cost R86. Additional labor, veterinary and marketing costs amount to R747/ha, and the extra 781 kg/ha of weight gain was valued at Rl, 562. Consequently, for both groups of lambs combined, total income, expenditure and profit/ha were R4,128, R2, 288, and Rl,840, respectively, and the total gain/ha was 2,064 kg.

CONCLUSIONS

The model developed in this study served as a useful first approximation to describe a fat lamb production system from rangeland and irrigated pasture. It should also serve adequately in convincing farmers of the economic benefits. In fact, the economic analysis was so favorable that bankers could likely be persuaded to offer loans to pay pasture production costs or to buy sheep. Irrigation obviously reduced the level of risk related to the system, compared to alternatives that rely on precipitation, which may be highly erratic.

Due to the high production cost of irrigated pasture and irrigation limitations on individual farms, total area under irrigated pasture would be a more serious constraint in fat lamb production as compared to farm size being the major restriction for extensive wool farming practices. However, farm sizes that were subeconomic under extensive wool farming practices should provide good earnings if relatively small areas could be irrigated for fat lamb production. For example, if a producer owned a 700-ha farm that included 675 ha of rangeland and 17 ha of irrigable land, he could expect to carry 675 ewes (1 ewe/ha of rangeland), finish all the lambs on pasture and earn R32,113. Based on an average gross margin of R21/sheep for wool producers in the area, the corresponding earnings from wool production would be R14,175. Despite the encouraging results obtained in this study, further research is needed to extend and refine the model so that discrepancies observed between predicted values and results achieved in the farm evaluation can be accounted for.

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Table 1. Effect of stocking rate and weaning weight on the number of days from birth to weaning, assuming only single births.

Stocking rate ewes/ha	Weaning weight of lambs (kg)				
	18 days	20 days	22 days	24 days	26 days
16	44	50	55	60	66
24	48	54	60	66	72
32	53	59	66	72	79
40	59	66	73	80	87

Table 2. Effect of stocking rate and weaning weight on the number of days from birth to slaughter, assuming only single births.

Stocking rate ewes/ha	Weaning weight of lambs (kg)				
	18 days	20 days	22 days	24 days	26 days
16	166	160	155	149	143
24	186	180	173	167	160
32	214	205	197	189	181
40	250	240	229	219	209

Table 3. Expected income, expenditure and profit/ha for different stocking rates, assuming only single births.

	Stocking rate (ewe/lamb pairs/ha)			
	16 rand	24 rand	32 rand	40 rand
Income/ha	1,280	1,920	2,560	3,200
Expenditure/ha	927	1,043	1,169	1,311
Profit/ha	353	877	1,391	1,889

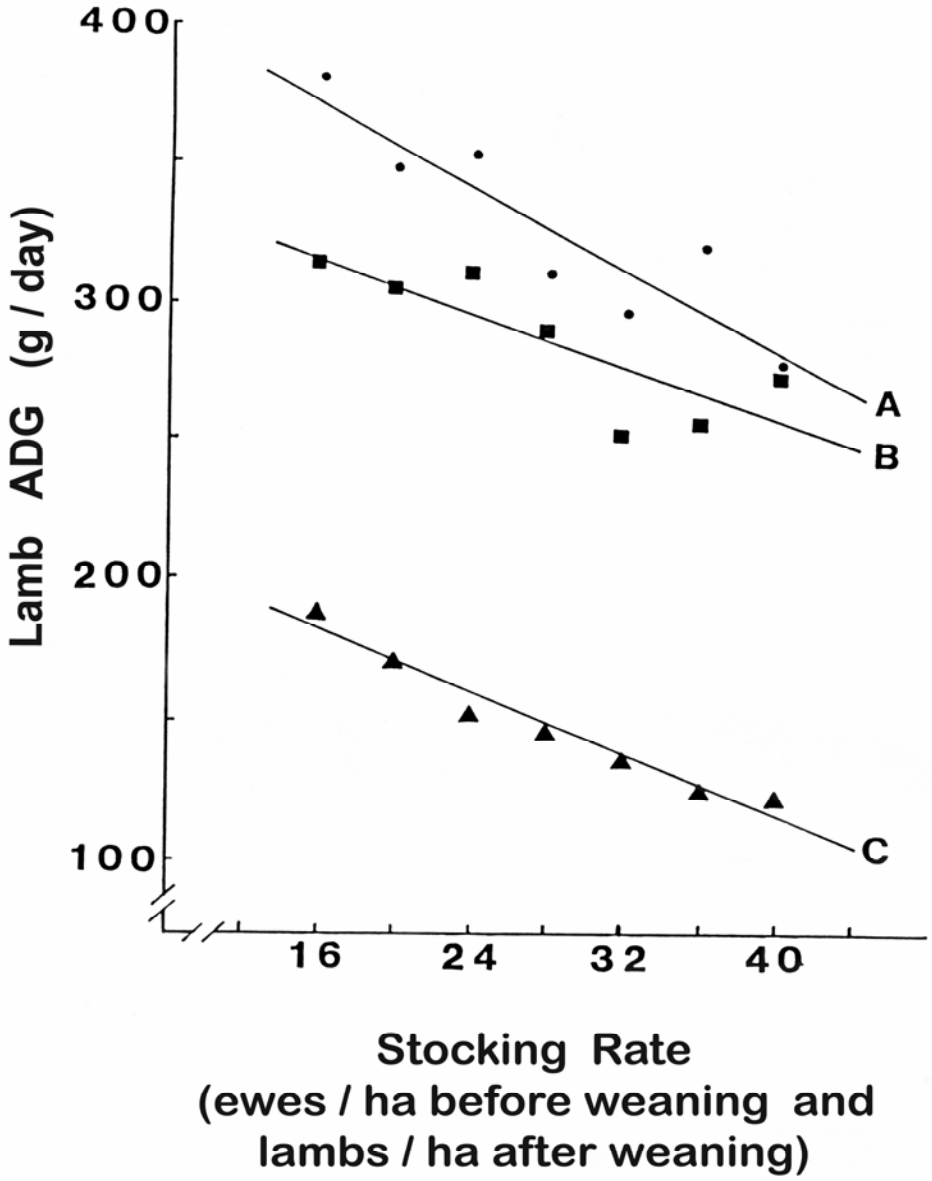

Fig. 1. Regression relationships between lamb ADG and stocking rate for (A) single lambs and (B) twin lambs before weaning and for (C) all lambs after weaning.

Regression equations: (A) $y = 432 - 3.76x$, $r = -0.91$
(B) $y = 354 - 2.43x$, $r = -.081$
(C) $y = 224 - 2.71x$, $r = -0.98$

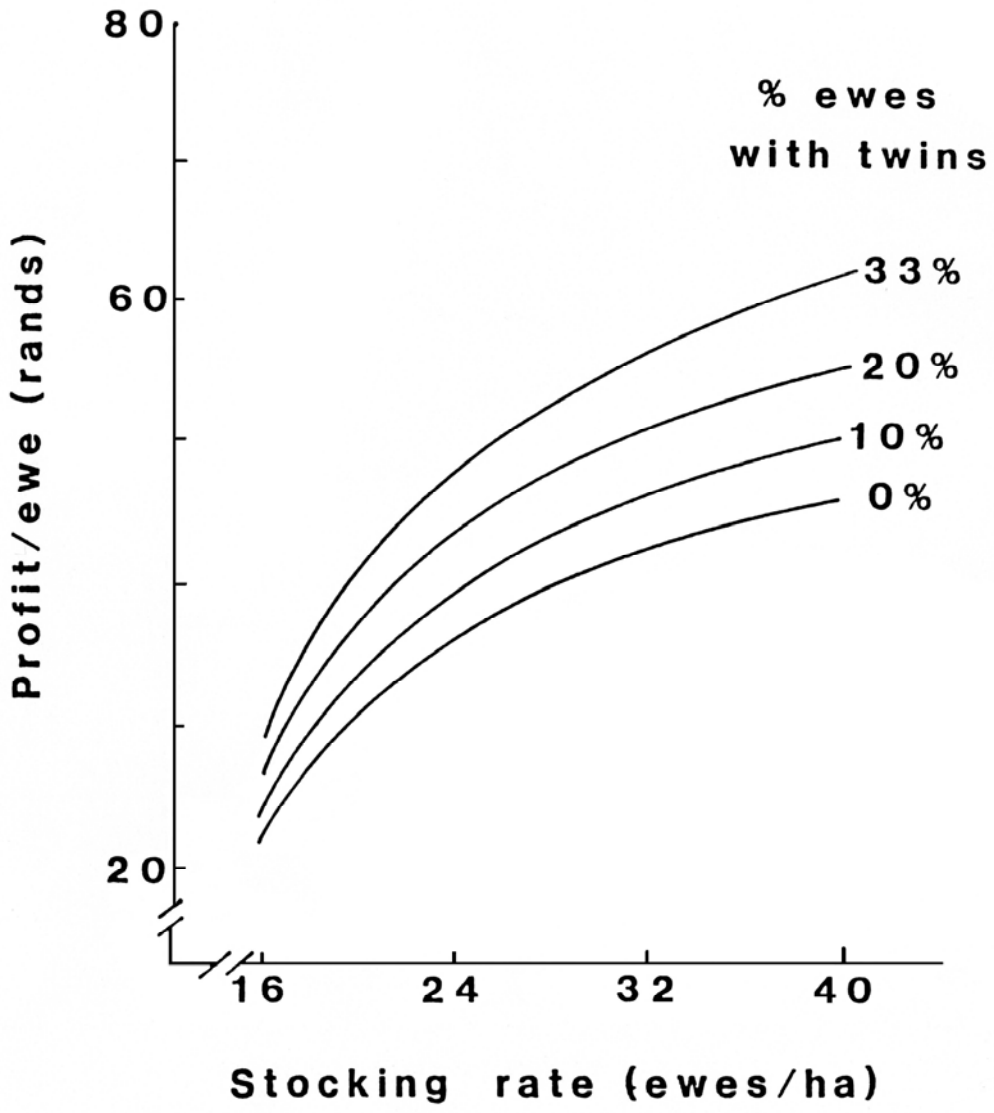

Fig. 2. Predicted profit/ewe for different stocking rates and proportions of ewes with twins.

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A BIOECONOMIC SIMULATION MODEL OF BEEF, FORAGE, AND GRAIN PRODUCTION IN WESTERN CANADA

K. K. Klein and B. H. Sonntag

INTRODUCTION

A broader understanding of agricultural production problems can be gained by synthesizing the viewpoints of several disciplines. Johnson (1974) noted that many problems faced by decision- (or policy-) makers are "so complex that the demands they place upon our disciplinary concepts, information, and quantitative techniques exceed the present capabilities of our discipline." Dillon (1976) argued that multidisciplinary research involving economists, biologists, chemists and other types of scientists facilitates a "synthesizing, integrative, team oriented outlook." Forming teams to meet a specific problem is a better approach to solving many of the practical problems facing agricultural decision-makers than is the traditional "analytical compartmentalizing and disciplinary" approach.

Dent and Blackie (1979) stated that a system "cannot be properly understood by an 'ad hoc' set of studies of the various elements that make up the system." The interrelationships are so important that the whole production system is more complex than the sum of its parts. Innis (1975) and Spedding (1975) noted that systems models of entire farm operations place in perspective the contribution of the various parts of the farm business. The risk of oversimplifying and drawing incorrect conclusions is increased if analyses are conducted on arbitrary subsystems.

Johnson (1974) suggested that economists should increase the emphasis on simulation modeling of agricultural systems. Simulation models permit decision-makers to explore the consequences of particular actions. The multidisciplinary nature of the problems generally precludes the use of optimizing models based on questionable or invalid assumptions (e.g., where the conditions necessary for maximizing behavior are not met). Musser and Tew (1984) echoed the view that simulation "does not propose to identify 'optimal' plans for firm managers. Rather it proposes to provide information which most likely has qualitative value for farm managers."

Simulation is an appropriate methodology for modeling a firm from the systems perspective. A simulation model can more easily accommodate the complex biological, physical and economic interrelationships involved in production than can models that use restrictive algorithms. Trapp and Walker (1986) suggested a number of reasons why simulation modeling was

[1]Associate professor, Department of Economics, University of Lethbridge, Alberta, Canada T1K 3M4; Director, Agriculture Canada Research Station, Swift Current, Saskatchewan, Canada.

superior to the more traditional methods of production function analyses:

- It can take account of interactions between decision-makers and control variables during the production period.

- Data on the effects of uncontrollable variables are often unavailable.

- Technology and factors of production change over time.

- Production is not timeless.

- Inputs are not homogeneous.

- Data are often produced piecemeal, i.e., date on the entire production process are often unavailable.

Dent and Anderson (1971) emphasized the importance of a flexible model structure for representing agricultural systems. If a formal algorithm is not relied on for solution, the model can be "as complex and as realistic as desired within the confines of available data and detailed structure of the real system being modeled." More important than obtaining optimal solutions is tracing the "detailed workings of the system" and being able to simulate the effects of decisions on the outcome of the firm.

The objective of this study is to construct a bioeconomic simulation model to aid in studying the beef-forage-grain production system at the farm level. By incorporating biological, physical and economic interrelationships among the enterprises, the resultant simulation model could be used to evaluate biological and physical research results, help determine research priorities, assist in analyses of farm-level effects of governmental policy initiatives and provide a realistic and capable extension and teaching tool.

OVERVIEW OF THE MODEL

The overall structure of this model was described in Klein and Sonntag (1982). Its genesis was the model of an Indiana hog-corn farm developed by Lee in his Ph.D. dissertation (1971). Lee was dissatisfied with farm-management decision models available in the late 1960s. They were either very simple partial-budgeting techniques usually done with a mechanical calculator or very complicated linear-programming models that required a great deal of computer time to solve. Both methods had major disadvantages. The partial-budgeting method implicitly assumed that enterprises could be totally separated, that costs for machines and buildings could be prorated by enterprise and that relationships between inputs and outputs were linear. The linear-programming method suffered from its algorithmic requirements of linear relationships and complete divisibility of activities. Though not critical when choosing the most profitable production plan, it had the effect of destroying confidence in the procedure by many users. Moreover, both methods relied on data

available from the farmer's records and experiences. They had no systematic way of accumulating and using highly technical research data available from many agricultural research institutions.

The systems model is structured to represent an operational farm unit. This is a decision-making entity that is identified by "legal and economic independence, by legal business relations and by management functions such as planning (and) control..." (Csaki, 1985). It is at the farm level where decisions are made regarding enterprise type, size and mix; allocation of labor, machines, credit and other resources; introduction of new technology; growth through internal and external capital generation; and control of deviations from the desired state by compensating or eliminating disturbances.

The farm-level focus of the model requires consideration of all major economic opportunities for a specific type of farm operation. A common type of farm operation in western Canada includes crop and beef enterprises. Often the beef enterprise is based on a forage resource that cannot be used for crop production. While several annual crops are available for the cropping enterprise in western Canada, they all entail similar resource requirements for their production. Most are spring-planted, fall-harvested cereal and oilseed crops. The beef enterprise, however, has much more diversity among farms. On some farms, the beef enterprise is a cow-calf operation where calves are sold at weaning time and the cows are overwintered on available forage that is of variable quality. Some farms have beef enterprises where calves are raised to heavier weights before sale; many farms do not sell their calves until they are finished to acceptable standards for slaughter. Other beef-producing farms are specialized feedlot operations where feeder calves are purchased for finishing at various sizes and dates. The forage enterprise is complementary to the beef enterprise; in some cases it may be competitive with the cropping enterprise. It varies greatly among farms and is dependent on soil and climatic conditions in the region, the type and scale of the beef enterprise and overall economic conditions in the crops and beef sector. Some farms have low-yielding native forage land available that cannot be used for other economic purposes. Other farms must use land for perennial or annual forage production that could produce saleable crops. In addition, some farms can use waste products such as straw for feed, or they may have available additional pasture resources through their involvement in community or cooperative pastures.

Decisions made in one enterprise may affect outcomes in not only that enterprise, but in other areas of the farm business as well. An expansion of the cattle herd usually results in a reduction in area available for the production of cereal and oilseed crops. It may also reduce labor time available during critical periods. Crops may have to be planted later, possibly reducing yields. The interactions among enterprises and resources on an operational farm can be shown in a comprehensive systems model.

Modeling at the farm level requires focusing on decisions that must be made by the manager. The manager must decide on deployment of resources that are available in the context of the economic and legal

infrastructure in existence. For example, rules regarding the deductibility of certain costs from income, for the purpose of paying a tax on net income, may affect the purchase and use of inputs. These decisions may also be conditioned by specific objectives of the farm manager. Patrick and Eisgruber (1968) contended that objectives shift with age, education and experience of the manager, level of indebtedness, family obligations and other considerations.

This model can simulate a wide array of production and management strategies among the beef-, forage- and grain-production enterprises over a 10-year planning horizon. Financial items of a personal and nonfarm nature are included; this permits even more diversity in terms of the farm-level analyses that may be undertaken.

THE PRODUCTION ALTERNATIVES

The production alternatives included in the model are illustrated in Fig. 1. They include six principal methods of producing beef:

1. cow-calf — sell weaned calves

2. cow-yearling — sell feeder yearlings

3. cow-calf-feedlot — weaned calves go directly to the feedlot and are sold as slaughter cattle

4. cow-yearling-feedlot — weaned calves are placed in a stocker program for about 5 months and then shifted to a feedlot finishing program

5. cow-yearling-pasture — weaned calves are placed in a stocker program for the winter, on pasture the following summer, and sold off-pasture as short-keep feeders

6. cow-long-yearling-feedlot — the same as (5) except that short-keep feeders are placed in the feedlot and finished to slaughter weight

Feeder cattle can be purchased on any farm that has a feedlot enterprise.

Four breeding methods are available:

- natural breeding
- one artificial insemination (AI), followed by natural breeding for cows that don't conceive
- two AIs, followed by natural breeding for non-conceiving cows
- AI only

Pregnancy testing is optional.

Shelter requirements are divided into three categories according to the type of cattle being sheltered — breeding herd, replacements and

stockers, and feeders. Three types of shelter are available for each category:

- minimal shelter, at a low capital investment
- sheds, at a medium capital investment
- sheds and drylot, at a high capital investment

The length of the winter feeding period for the cow herd can vary from 0 to 6 months.

Three rate-of-gain options can be used for feeder calves:

- low — 2 lb/day for steers, 1.7 lb/day for heifers
- medium — 2.25 lb/day for steers, 1.9 lb/day for heifers
- high — 2.5 lb/day for steers, 2.1 lb/day for heifers

Three rate-of-gain options can be used for feeder yearlings:

- low — 2.2 lb/day for steers, 1.75 lb/day for heifers
- medium — 2.5 lb/day for steers, 2l b/day for heifers
- high — 2.8 lb/day for steers, 2.25 lb/day for heifers

Five diet options consisting of specified combinations of hay, grain and pasture are available for each class of animal (or feeding period in the case of the breeding herd). The diet options available for feeders depend on the rate of gain selected for each type of feeder. When high rates of gain are selected, diets with high forage contents are not feasible.

The high-forage diets are specified in a manner consistent with minimum energy-concentration limits for specific rates of gain. When high-grain diets are used with low rates of gain, it is assumed that intake is restricted by rationing.

Seven pasture types are available in the model:

- Native 1 (unimprovable) — represents rough native pastures that are unimprovable because of topography, stones, soil type, etc., and can, therefore, be used only in their native state

- Native 2 (improvable) — includes pasture that is under native vegetative cover but can be improved during clearing, breaking and reseeding

- improved — represents rangeland (Native 2) or cropland seeded to species particularly adapted to early-season use, such as crested wheatgrass, which is commonly used in the semiarid prairie areas

- irrigated pasture — represents a species suitable for irrigation

- community pasture — represents pastures with an administered stocking rate and fixed per-head or animal-unit rental rate

- stubble — includes cereal stubble available for grazing in the fall or winter, basically a salvage operation

- aftermath — includes regrowth on perennial hay land that is available for fall or winter grazing

All pastures can be used in a number of ways. Some can be grazed all year in certain areas. Others are available only at certain times of the year. Four pasture seasons are identified in the model:

- spring — May 7 to June 3 (4 weeks)
- summer — June 4 to September 23 (16 weeks)
- fall — September 24 to November 18 (8 weeks)
- winter — November 19 to May 6 (24 weeks)

Pasture-improvement alternatives associated with growth or no growth in the breeding herd are available in the model. Pasture can be improved (within the constraints of the farm situation) to remove the deficit in pasture production for the current herd or for 5%, 10%, 15%, 20%, 25% and 30% increases in the breeding herd.

Five methods of improving native rangeland (or increasing the area of tame pastures) can be simulated in the model:

1. improve native range through reseeding with tame grass species

2. seed tame grass species on cropland area

3. fertilize present area of improved pasture

4. improve native range and fertilize improved pasture (combination of alternatives 1 and 3 above)

5. seed cropland to pasture and fertilize improved pasture (combination of alternatives 2 and 3 above)

Breaking can be done in the summer or fall with the farmer's own machinery or by custom operators.

Pasture improvement can be financed by cash or loans of different terms.

Eight methods of harvesting forages are available in the model:

- swath, bale, load on self-propelled stack wagon, haul at harvest

- swath, bale, load on pull-type stack wagon, haul at harvest

- swath, bale, haul with loader and trailer at harvest

- swath, bale with giant round baler, haul with loader and trailer at harvest

- swath, bale, stock, haul with loader and trailer in the fall

- swath, bale with giant round baler, haul with loader and trailer in the fall

- swath, stock with loose hay stacker, move with stack mover

- swath, harvest as silage with forage harvester and forage wagon

The grain enterprise is not modeled as comprehensively as are the other enterprises in this model. It is meant to represent a feed-grain-and-oilseed-producing enterprise in a manner suitable for calculation of resource requirements, and thereby permit an analysis of enterprise interactions on a multienterprise farm.

Four types of rotation are available in the model:

— 1/2-crop
— 2/3-crop
— 3/4-crop
— continuous crop

The model contains three crops — barley, rapeseed and cereal forage. Barley represents all cereals, and rapeseed represents all oilseeds. Rapeseed can be produced on a maximum of 50% of the planted area if the 1/2-crop or the continuous-crop rotation is selected. If the 2/3-crop or the 3/4-crop rotation is selected, rapeseed can be produced on any portion of the summer-fallow area but not on stubble area. Cereal forage is limited to 50% of the planted area. The area of cereal forage depends on hay requirements and quantities of perennial hay and feed straw produced.

For some operations the specific type of machine to be used can be selected. The operations and alternative machines for performing them are as follows:

- planting — press drill, hoe drill or discer and packer
- spraying — own or custom sprayer
- swathing — pull-type or self-propelled swather
- combine — pull-type, self-propelled or custom combine
- summer-fallow — seven alternative tillage machines

Machines can be purchased either new or used. They are replaced on the basis of hours of their useful life. They can be sold at the end of any year in which their accumulated hours of use do not exceed 100% of their maximum useful life.

Four financing alternatives are available for land purchases:

- cash
- 30-year mortgage
- 20-year mortgage
- Perpetual mortgage

The quantity of land purchased over time can be specified in the input form.

The following pre-seed operations are performed for crops grown on fallow:

- Prairie farms (brown and dark brown soil zones) — if the discer-and-packer planting method is used, no pre-seed tillage operations are performed on fallow; if drills are used, one pre-seed tillage operation is performed.

- Parkbelt farms (black soil zone) — two pre-seed operations are performed with discer and packer planting; three pre-seed operations are performed with drill planting.

A fall tillage operation is performed on all land that is to be stubble-cropped. If the discer-and-packer planting method is used, one additional pre-seed operation is performed in the spring; if a drill method is used, two additional operations are required. A post-planting harrowing operation is performed on all stubble crop area.

BIOLOGICAL CONSIDERATIONS

The model includes 10 classes of beef cattle: male and female calves, two ages of replacements, male and female stockers, male and female feedlot animals and the breeding herd of cows and bulls. Maintenance requirements of each of these classes of cattle are computed for each biweekly period during the year.

Energy and protein requirements are calculated separately for each class of cattle. Salt, calcium, phosphorus, vitamin A and trace nutrients are aggregated into a cash-costs category.

The general form of the energy requirements equation is given in (1):

$$DE_{ik} = (a_i W_{ik}^{.75} G_i) E_i \qquad (1)$$

where:

DE_{ik} = digestible energy requirement (kcal) per day for animals of class i (i = 1, 2,...,10) in biweekly period k
a'b = constants that are specific to each class of cattle
W_{ik} = weight (lb) of animals of class i in time period k
G_i = daily rate of gain (lb) of animals of class i
E_i = feed efficiency index of animals of class i.

Weights and, hence, DE requirements change each biweekly period for animals that are gaining or losing weight.

Crude protein (CP) requirements depend on weight, rate of gain and biological function of the animals and are calculated as follows:

- bulls: $CPR_i = 0.08F_i$
- dry, pregnant cows: $CPR_i = 0.065F_i$
- growing animals: $CPR_i = 0.4566 + 0.00081W_i + 0.276R_i$ (2)

where:

CPR_i = crude protein requirements (lb/day) for animals of class i
F_i = air dry weight (lb) of all feedstuffs consumed by animals of class i
W_i = weight (lb) of animals in class i
R_i = rate of gain (lb/day) of animals in class i

Crude protein consumption (CPC) depends on diet composition and protein content of the component feeds. The CP content of a diet is calculated from the proportions of perennial hay, cereal hay, straw and grain in that diet. Consumption of crude protein from these sources is estimated and compared with CPR. If CPR is greater than CPC, a protein supplement is purchased.

Bulls and cows are maintained at their specified weights. Mature cows are assumed to lose twice the birth weight of the calf when giving birth. This weight is regained during the pasture season. Bred heifers gain at a rate such that their weight at first calving is 90% of mature cow weight. Weight loss at calving is twice the calf birth weight. This loss is assumed to be regained by the time the calf is weaned. Replacements reach mature weight by the time they have their second calves.

The birth weight of calves is exogenous to the model. Weaning weights depend on birth weight, sex, time of calving and growth rate. Weights for stockers, yearling feeders and slaughter animals at any given time depend on weaning weight, sex and rate of gain. Relative rates of gain of steers and heifers change as they get older. Rates of weight gain for heifers range from 0.92 of the daily gain for nursing male calves to 0.75 for long yearling feedlot males.

The number of bulls required for breeding purposes is dependent on the breeding method selected.

The amount of forage that enters the pasture supply in each biweekly period depends on the area of each type of pasture, the use rate and the yield.

To maintain pastures in a productive state, only a fraction of total growth can be harvested. The proportion that can be harvested while maintaining such a state depends on the species, method of use, precipitation, pasture condition and other factors. Use rates are lowest when grazing begins near the start of the growing season. When grazing is delayed into the summer season or later, use rates can be increased.

Pasture yields vary widely from year to year; hence a constant level of carryover is impractical. Use rates can be increased in dry years without damage to the range if they are compensated for by reduced use

rates and higher carryovers in wet years. The use rates are adjusted in the model as follows:

$$U_{ij} = U_{ij} + (1 - U_{ij})*(1 - Y_t) \quad (3)$$

where:

U_{ij} = use rate of pasture type i for use method j
$\bar{U}_{ij}$ = use rate for $Y_t = 1.0$, i.e., average rainfall
Y_t = pasture yield index in year t (1.0 = average)

When yield (rainfall) is below average ($Y_t < 1.0$), use rates are increased and vice versa.

Pasture yields are highly variable. They depend on species, seasonal precipitation levels, soil fertility, range condition, site (soil type and topography), use method and other factors. The pasture yield index in the model is selected each year from a distribution within a range of 75% to 134% of average. Yield variability due to precipitation variability is higher when the range condition is low than when it is high.

A pasture-deterioration factor is also incorporated into the forage component of the model to reflect dry matter losses due to factors other than consumption by cattle. Pasture balance is reduced in periods outside of the growing season to account for this.

The DE requirements for each type of animal for each biweekly period are converted to quantities of hay, grain and pasture on the basis of the diet selected and average DE values for these three feed categories (1,000 kcal/lb of air dried feed for hay and pasture and 1,550 kcal/lb for barley). Equations (4), (5) and (6) describe how pasture production and consumption are reconciled in the model.

$$P_k = P_{k-1} + (PP_k - PR_k)/2{,}000 \quad (4)$$

$$PP_k = \sum_{j=1}^{5} PA_j Y_t R_t U_{ij} YD_{ij} \ (1.0 - PD) \quad (5)$$

$$PR_k = \sum_{m=1}^{10} AN_{km} DE_{km} PPH_m/1{,}000 \quad (6)$$

where:

P_k = pasture balance (tons of dry matter) in period k($k \geq 10$)
PP_k = pasture production (lb DM) in period k
PR_k = pasture requirement (lb DM) in period k
PA_j = acres of pasture type j
Y_t = average yield (lb DM/acre)
R_t = rainfall index in year t ($.75 \leq R \leq 1.35$)
U_{ji} = use rate for pasture type j and use method i

YD_{ij} = yield index for pasture type j and use method i
PD = pasture-deterioration rate
AN_{km} = number of animals of type m in period k
DE_{km} = digestible energy requirement (kcal) of animal type m in period k
PPH_m = proportion of DE from pasture for animal type m

In addition,

AN_k = f (enterprise size, breeding system, production system calving rate, mortality rate)
DE_k = f (weight, rate of gain, feed efficiency)
PPH_m = f (diet, feed supply)

If P_m becomes zero, PPH is set equal to zero, and hay or grain is substituted for pasture in the diet.

Dietary considerations place limits on the amount of straw that can be used for feed. The proportion of the forage component of the diet that can be satisfied by straw depends on the class of animal, the forage/grain ratio in the diet, and the source (perennial or cereal hay) of the nonstraw forage part of the diet.

ECONOMIC CONSIDERATIONS

The objective criterion most commonly used in the model is maximum terminal net worth. However, minor modifications will permit additional objective criteria such as maximum average net farm income or lexicographic criteria such as maximum terminal net worth subject to minimum income or constraints on growth during each year.

All accounting is done biweekly. Cash inflows and outflows (including consumption and expenditures[2]) are computed during each 2-week period. Tax withdrawals, loan payments and other injections and withdrawals of cash are made at specified time periods during the year. A biweekly cash balance is computed.

Production and use of other resources and intermediate products are also calculated biweekly. The various items include grain, hay and pasture production and use and labor use by enterprise.

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[2]Consumption expenditures are withdrawn biweekly on the basis of the following annual consumption function:

$$C = Ca + cN$$

where:

C = total consumption withdrawal ($)
N = annual net income ($)
Ca = minimum living expenses ($), specified
C = proportion of net income withdrawn for consumption ($),specified

The labor requirement for cows and replacements is a function of herd size. The proportion of annual labor requirements varies during the year.

Scale economies can also result from the use of larger machines. Operating costs of tillage, planting and harvesting machines are dependent on the draft per foot of width, operating speed and field efficiency. The model includes from 4 to 10 sizes of each machine. Tractor operating costs are based on the above factors plus the horsepower-related fuel consumption.

Depreciation of each machine is calculated using its remaining value for future use on the farm. The remaining farm value functions are calculated as:

$$RFV_i = (a)REPT(b)^{AGE} \tag{7}$$

where:

RFV_i = remaining farm value ($) of each machine in the inventory having depreciation code i(i=l,2,3,4)
REPT = replacement cost of machine ($)
AGE = age of machine in years
a,b = constants that are specific to each type of machine

Machine repair costs are based on annual hours of use and age and replacement costs of each machine. Repair and maintenance costs are calculated as

$$REP_i = a\ H^{bl}Y^{b2} \tag{8}$$

where:

REPi = repair costs ($/hr/$l,000 replacement cost) for machines of class i (i=l,2,...,10)
H = annual hours of use of the machine
Y = age of machine (years)
a, b_1, b_2 = constants specific to each type of machine

INPUT AND OUTPUT

An input form is used to specify parameters for a given farm situation and to modify research results that are embedded in the model. A completed input form contains the following data:

- beginning inventories (January 1) of land, buildings, machines, livestock, products and financial items, with details on type, capacity, amount and age

- permanent and seasonal availability of labor, on a biweekly basis

- prices for outputs and inputs (if different from values in the base data file)

- technical transformation rates, e.g., conception rates for livestock (if different from values in the base data file)

- specific production plans to be evaluated

- personal consumption requirements and taxation status

- values for certain parameters to control operation of the model, e.g., number of years and number of production plans to be evaluated

Output from the model contains several types of tables; the number and printing frequency of the tables are controlled through switches in the input form. The following data are contained in tables produced by the simulation model:

- physical activity levels — number of livestock, acres of grain, rotation, etc.

- ending inventories for each year, including remaining farm value of all assets

- financial situation — assets, debts, net worth, cash balance

- resource flows — cash receipts and expenses, labor use, crop production and use, product sales, etc.

APPLICATION OF THE MODEL

The model was recently used to identify and document methods that could be used to improve productivity in the Alberta cow-calf industry. Specifically, the impact on returns per cow by adopting some commonly recommended breeding and culling practices was estimated. Only brief details of this analysis are provided here; the full study is reported in Klein (1984).

Five mixed beef-forage-grain representative farms from the Red Deer-Vegreville area of Alberta, Canada, were chosen for analyses. These representative farms were of various size and enterprise ratios. The crop enterprises ranged from 55 ha to 400 ha of cropland; the beef enterprise ranged from 20 to 143 cows. The size distribution of representative farms was developed on the basis of the most common categories of herd size reported in the 1981 Census of Canada. The land base accompanying each herd was based on several sets of data, including carrying capacities of Alberta pastures and ratios of pasture land and grain land to beef cattle herd sizes. The procedure was intended to match forage land to herd size since it is believed that most beef-producing farms are organized so that they can on average produce enough forage to feed their herds.

A number of plausible alternatives to common breeding and culling practices were tested. The breeding season was shortened from 12 weeks to 8 weeks to reduce the number of late breeders. In addition, pregnancy checking was practiced to identify all open cows; they could then be culled in the fall to save on winter feeding costs. The costs of pregnancy testing are $2.50 per cow adjusted upwards by 33% for herds smaller than 80 cows and downwards by 33% for herds larger than 150 cows. Semen evaluation was practiced on herd sires at a cost of $35.00 per bull. In anticipation of a shorter breeding season, cows were assumed to be flushed prior to the breeding season. It was assumed that this was accomplished by increasing the feed requirements by 10% for the months of May and June; this was met by feeding the cows supplementary grain. Labor requirements were increased by a total of 0.25 hours/cow to facilitate all practices. Conception rates were increased to 75%/service from 65%/service. Cows started cycling 7 weeks after calving instead of the average 10 weeks, reflecting the benefits of these practices.

Results from adoption of these farm practices showed increases in cull cow sales on some farms and calf sales on all farms. Cull cow sales were not up significantly, suggesting that increased conception rates and a shorter interval between calving and the start of cycling practically cancels the effect of a reduced breeding season.

Increased calf sales resulted from higher conception rates. Cattle receipts were found to be higher due primarily to more calves being sold at heavier weaning weights as the calf births were bunched closer to the start of the calving season.

Forage requirements were increased due to more feeder calves and older calves on average, each consuming more feed on pasture. Pregnancy testing with subsequent culling each fall resulted in some saving in winter feed. The net result was still an increased forage requirement. Grain fed was higher with the improved practices, a result of flushing the breeding herd before the breeding season. The increase in feed requirements caused grain receipts to drop as less barley was sold and more cereal hay was needed.

Cattle expenses also increased due to costs of pregnancy checking, sire evaluation and transporting and selling of additional calves.

The overall financial result was that increased cattle receipts were substantially offset by reduced crop receipts and increased cattle expenses. This translated into increases in net farm income across the five farms of $1 per cow to $5 per cow. In addition, labor requirements were slightly higher for all farms.

Though the financial results of this analysis are not particularly impressive, they reveal the biological and economic interrelationships that ordinarily complicate an economic evaluation of changes in production practices. All too often, simple partial-budgeting techniques have been used to assess changes in technology at the farm level. A comprehensive systems model that is based on scientifically derived data can provide a framework that incorporates all appropriate

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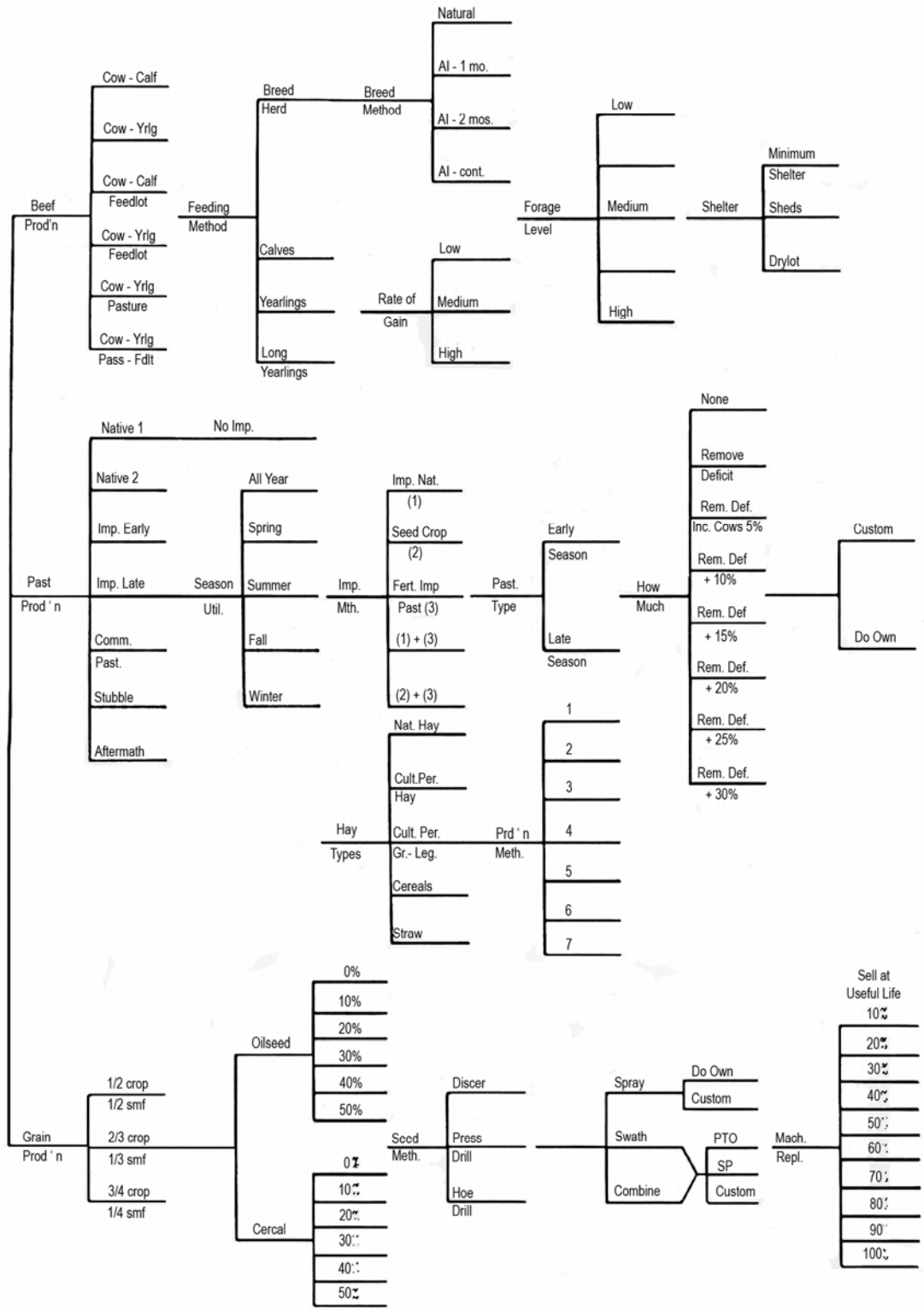

Fig. 1. Schematic of beef, forage and grain production alternatives.

HOMESTEAD IN FSR: STRATEGIES AND EXPERIENCES FROM BANGLADESH

R. E. Hudgens, M. Z. Abedin, and M. H. Khan[1]

INTRODUCTION

In most Asian countries, field research in the design and testing of new production technologies using the farming-systems-research (FSR) approach has generally given initial attention to the cropping component of farming systems. In the course of time, emphasis has slowly shifted to include other system components, such as the livestock and forestry subsystems. The homestead subsystem is commonly the last to receive attention, and then the attention it gets often consists of only a token gesture at commercializing vegetable production in the backyard garden or improving poultry husbandry for profit.

Although the contribution of homestead production to family nutrition and cash income is widely recognized (Chondhury et al., 1985; Khan, 1983; McCarthy and Feldman, 1983), few efforts have treated the homestead as equal to other subsystems in the application of FSR methodologies. In South Asian countries such as Bangladesh, where women have few employment opportunities outside the home, the role of women in decision-making and as a source of labor for homestead production is especially noteworthy (Alter, 1986). Therefore, FSR attention to the homestead as a subsystem can be justified from the standpoint of efficient use of farm-family labor resources.

Furthermore, a large percentage of rural families in Bangladesh and other South Asian countries do not own land outside the homestead. Homestead production takes on special significance for these "landless" farmers, who are frequently overlooked in FSR activities (BRAC, 1984). Landless farmers are often classified as "agricultural laborers" whose resource base is too limited to offer many development options.

Importance of Homestead Production Worldwide

Food production on homesteads, in the form of backyard gardens, fruit trees and small animals such as chickens, is a characteristic of the majority of rural homes worldwide. However, in developing countries, especially those countries with high population concentrations on the land, such production assumes increasing importance to family well-being. Ninez (1984) classified backyard gardens into two general types: "subsistence gardens" that produce condiments, leafy vegetables and fruit to complement staple foods produced from field crops and "budget gardens" that provide replacements for or supplements to purchased food supplies in homes where family income is derived from wage labor,

[1]Farming systems specialist (Winrock); chief scientific officer, On-farm Research Division (BARI); National Farming Systems coordinator (BARC).

especially in areas where purchased food items are expensive or where fresh vegetables and fruits are unavailable.

Both of these garden types use family labor exclusively and are located on land areas considered too small for field-crop production. Homestead gardens provide insurance against field-crop failure and the disruption of food supplies in local markets. On farms with more limited land resources, such as those in South Asia, the agroforestry component of the homestead provides building materials and fuelwood for the households. Farm animals are corralled in homestead structures each night.

There is also a convenience factor in homestead production — vegetable beds, fruit trees and animals are near the family dwellings. This is particularly important where luxury fruits, valuable animals or scarce vegetables are raised under the close surveillance of the family. Petty cash is generated from the sale of garden surpluses at certain times during the year, particularly on homesteads near urban areas. In more isolated villages, reciprocal exchanges of surplus fruits and vegetables are made among villagers and extended family members (Ninez, 1985).

Description of FSR in Bangladesh

As in many other Asian countries, FSR in Bangladesh evolved from on-farm research with rice-based cropping systems. Fortunately, the sequential stages of FSR methodology are similar to those of cropping systems research, which allowed for a rapid transition of methodologies. However, staffing multidisciplinary teams at each site proved more difficult, especially within institutions with a mandate to promote a specific cash crop (e.g., the Bangladesh Rice Research Institute, Bangladesh Jute Research Institute, Sugarcane Research and Training Institute, etc.).

Organization. The National Coordinated Farming Systems Research Program (NCFSRP), with seven member institutions[2], began operations in 1985. At present, work, is being conducted at 25 sites. Each institute has organized a multidisciplinary "task force" to provide guidance and technical support for its FSR teams in the field. Interinstitutional coordination is provided by the National Technical Coordination Committee for Farming Systems Research at the Bangladesh Agricultural Research Council (BARC). All seven research institutions work closely at the regional, district and village levels with personnel from the Department of Agricultural Extension (DAE).

Classification of Subsystems. In an effort to understand how farmers allocated resources and to identify production constraints for FSR attention, farming systems were subdivided into crop, livestock, agroforestry, fisheries and homestead subsystems. Each subsystem was further divided into technical components. Major interactions between subsystems were identified prior to FSR intervention. The stratification of farming systems into subsystems and technical components of subsystems is helpful in technology development given the

institutional composition and academic specializations represented in the Bangladesh NCFSRP.

However, including the homestead as a subsystem provoked much discussion within the NCFSRP. Some social scientists viewed the homestead as "the system." They argued that all other disciplinary subsystems such as crops, livestock, forestry, etc. are variables within the farming community, existing on farms where resources permit. On the other hand, as is clearly exemplified by the large percentage of landless farmers with homestead production units, the homestead can exist in isolation.

Social scientists defined the farming system as the area occupied by the family unit and used in any way for food production. They argued that all subsystems are disciplinary in nature, with academic programs offered in specific aspects of crop science, animal science, forestry, weed science and fisheries. However, there is no single academic discipline for homestead production. They cited the institutional research structure of Bangladesh, with specific institutes for different crops, livestock and forestry, but none for the homestead.

Biological scientists, on the other hand, were not completely in agreement with this point of view, arguing that food production and income generation had a technical basis and that the homestead area of the farm unit was at best simply the focal point for interaction of other subsystems rather than a subsystem or complete farming system unto itself. In their view, homestead production could be improved by successful FSR programs in crops, agroforestry, fisheries and livestock.

Nevertheless, it was agreed that no single institution existed for targeting the multidisciplinary complexity of homestead production. Moreover, in a country such as Bangladesh, where women are confined to the homestead by cultural and religious pressures, the role of women's labor in family nutrition, income generation and postharvest operations would be totally ignored if the homestead was not given equal footing with other subsystems. Therefore, a consensus was reached that a special multidisciplinary and multi-institutional work group was needed to extend FSR investigation to the homestead as a subsystem for all classes of farmers.

THE HOMESTEAD PRODUCTION UNIT IN BANGLADESH

With approximately 90% of Bangladesh's population residing in rural areas (Jansen et al., 1983), farming is the dominant way of life. The majority of farms operate at a subsistence level, and as the world's largest rice importer and largest recipient of food aid, Bangladesh is far from food self-sufficiency. Recent trends in increased food production have been outpaced by population growth, so additional increases in food imports are expected in the future. At present, most of the rural poor suffer from malnutrition. Nutritional surveys have shown significant dietary deficiencies of calories, protein, calcium, iodine, iron and the vitamins A, C, riboflavin, niacin and thiamine (Greene, 1986; Douglas, 1983).

The homestead in Bangladesh is defined by the Bengali work, "bari," which refers to the living area of extended family members. It includes the homesite dwellings, land, ponds, plants and animals and excludes, by definition, commercial field crops and cereal staple crops. The bari is generally built on a mound raised above surrounding farmland. The extra earth required for constructing this mound is usually obtained from digging ponds, and the mound area itself is protected from erosion by live fences of trees and shrubs. The typical homestead contains dwellings, livestock sheds, a vegetable garden, a threshing area and trees, including bamboo. During the monsoon season, when approximately one-third of the arable land is flooded, clusters of homesteads on these mounds form tiny islands surrounded by submerged farmland.

In a survey of homesteads across agroecological zones, Khaleque (1987) found that homesteads ranged in size from 0.02 ha to 1.41 ha, and represented about 17% of the usable land area of the average farm. However, in a similar study, Uddin et al. (1985) found that 53% of the homesteads sampled had a surface area of less than 0.1 ha, and that the average size of the homestead of the landless was 0.06 ha. They also noted that there was a positive correlation between farm size and the area planted in spices, including ginger, turmeric, garlic, onions and chilies. Saadullah (1986) reported a similar correlation between farm size and composition of the livestock subsystem, with a larger number of goats and cows on smaller landholdings.

The productivity of the homesteads varied by classification of farmers (Chondhury et al., 1985; Greene, 1986; Sara and Shah, 1985). Obviously, farmers in the "landless" category who owned a house but worked as wage laborers on land owned by others produced much less foodstuffs on their homesteads than did farmers who owned land. Nevertheless, the role of the homestead in supplementing family nutrition of landless households and the income generated by women through rice threshing and cottage industries is easy to overlook. Reciprocity or the seasonal "exchange sharing" of surplus homestead produce with neighbors and other villagers is an important insurance policy against crop failure, loss of off-farm employment or other interruptions in family income and food supply (Gupta et al., 1986).

Description of Components

Numerous case studies have been conducted on homesteads throughout Bangladesh (Baksh, 1985; Chondhury et al., 1985; Rahman, 1981). Homestead production in Bangladesh involves intensive use of the limited land area. Gupta et al. (1986) found that ecological factors determined the range of economic enterprises on a homestead, market accessibility defined the scale of the economic enterprises, and farmers' risk perception determined the allocation of farm resources among the different enterprises. The level of risk perception varied seasonally, according to the likelihood of floods and droughts.

Most of the work on the homestead involves hand tools and family labor without major capital investments (Sara and Shah, 1984). There is a high species diversity of both plants and animals, and in some cases there are daily as well as seasonal harvests (Wilson-Moore, 1987). The

planting of vegetables and fruit trees often appears to be random and in a mixed pattern, with many vines purposely planted to climb onto the roof of adjacent structures and onto trees. This reflects a vertical as well as horizontal use of available space.

Poultry, ducks, vegetables, spices and trees are all produced in different combinations on the homesteads of farms in Bangladesh. Both cattle and goats are housed on the homestead to allow the collection and use of dung (Khan et al., 1986). The economic contribution of women, who make up approximately *50%* of the labor resources of the country, is particularly important in homestead production (Khan, 1983; McCarthy and Feldman, 1983; Wallace et al., 1987). Most of the postharvest operations of threshing, drying and food storage are handled by women on the homestead (McCarthy, 1981), and it is here that many of the most interesting systems interactions occur.

Trees are used as living fences around the homestead for privacy and protection from the climate. Some of the trees (see appendix A) provide spices (e.g., bay leaves, cinnamon, etc.), while others (e.g., castor bean, arguna, etc.[3]) are used for medicinal purposes (Hussain and Gupta, 1986). Others, such as jackfruit and mango, are multipurpose, supplying fruit, timber and fuel. Young shoots of the drumstick tree are often eaten as vegetables, while jackfruit leaves are fed to goats and sheep (Camacho, 1986). However, agroecological factors determine the botanical composition of the agroforestry component in homesteads throughout the country. (The largest variation is found in the presence of trees like blackberry, banana, neem, date palm and coconut (Hussain and Haque, 1986)).

Manure from farm animals is packed onto jute sticks and dried at the homestead for fuel (Howes and Jabbar, 1986). Irrigating vegetable beds from homestead tube wells enhances tree growth during the dry season (Camacho, 1986). Tree leaves and sometimes water hyacinths from ponds and ditches are used as a mulch to conserve soil moisture in vegetable seedbeds, and many of the vitamins in family nutrition come from fruits and vegetables produced on the homestead (Begum et al., 1986). The homestead functions as the nucleus of the farm unit, and as such it is the point at which all other disciplinary components intersect.

Gender Issues in Decision-making

Several studies have been conducted in Bangladesh on the issue of decision-making by gender (Begum et al., 1986; Gupta et al., 1986; Khandker, 1983). These have dispelled the myth that women make all the decisions on the homestead, while men make all the decisions related to field crops. However, Uddin et al. (1985) noted that wives were the main decision-makers on the homestead and that female labor accounted for the bulk of the labor in the homestead garden. Data from a case study of the Channa village, Gazipur (Gupta et al., 1986), supported this contention. The women there had expressed a need for bottle-gourd varieties with a larger number of smaller fruit so that small trees, the animal shed and other buildings could support the weight of the fruit-bearing vines more easily. This suggests that women make management decisions on the varietal composition of the homestead garden. However,

the database that is currently available is insufficient to generalize on decision-making in regard to the sale of trees and livestock, the area planted to each plant species on the homestead, the timing and quantity of produce marketed, etc., for each farm classification.

Division of Labor

The use of female labor in postharvest operations and livestock management has been well documented through observation, informant interviews and time-allocation studies (Halim and Hossain, 1981; Hassan, 1978; Marum, 1983). In one study, both men and women planted and tended trees in 75% of the households surveyed (Khaleque, 1987). In only 20% of the households were men solely responsible for this task. In another study, both men and women were actively involved in rice threshing[4], but women were primarily responsible for soaking, winnowing, drying, parboiling, husking and storing rice (McCarthy, 1981). Khaleque (1987) noted that since women are responsible for stall-feeding livestock and collecting firewood for cooking, they are particularly interested in looking after trees for fodder and fuel.

Wallace et al. (1987) pointed out that gender roles overlap in agricultural work, the generation of supplementary income and tasks around the house, but that children normally assumed the duties performed by the adult role models of their gender. Women assist their husbands in the care of cows, goats, chickens and ducks and in the harvest of crops. However, men assume responsibility for land preparation, irrigation, fishing, washing cattle, making decisions pertaining to the domain of field agriculture and handling business matters, such as buying or leasing land, selling animals, etc.

While the extent of the participation of women in homestead management is dependent on the age of the individual and size of the family, normal housework consists of cooking, cleaning the house and animal sheds, collecting cow dung for drying, washing clothes, gathering firewood and water, maintaining fences and other homestead structures, looking after livestock and caring for children. Most of the women's work is highly routinized and repetitive. Postharvest work is in addition to normal household chores, which are often carried on simultaneously.[5] On the other hand, the basic household chore of men is the daily trip to the market.

Interaction of Subsystems

The system interactions that occur on homesteads are extremely complex and reflect class, time and location specificity. However, at the simplest two-way interaction level across subsystems, several interesting interactions have been noted in Bangladesh. Some examples follow.

Crop x Livestock Interactions. After threshing, rice straw is brought to the homestead and stored as a feed for ruminant livestock. This provides ruminant livestock with an important source of fodder throughout the year, but especially during the dry winter season when other feedstuffs are particularly scarce. Ruminants also forage on

cropland immediately after harvest[6] and are fed weeds removed from crop fields during weeding operations; on those farms with sugarcane, they are fed sugarcane tops at harvest. Poultry feed on shattered seeds after harvest and threshing. Snails are also collected from cropland during the crop-growing season to feed ducks on the homestead; this practice also reduces pest damage to crops (Hussain and Gupta, 1986).

Cattle are commonly recognized as major sources of draft power for cropland preparation and tillage in Bangladesh. However, less is mentioned concerning their involvement in transportation and postharvest operations, such as rice threshing. Likewise, the sale of livestock and livestock products to generate capital, which is then used to purchase crop agrochemical inputs, is often overlooked.

Vegetable x Forestry Interactions. Since an important gender distinction exists in labor allocation and decision-making between field crops and homestead garden crops on farms in Bangladesh, it is necessary to separate the interactions involving crops from those involving vegetables. On homesteads with access to irrigation facilities, the irrigation of the vegetable garden during the dry season provides much-needed moisture for the adjacent fruit trees (Camacho, 1986). Tree leaves, in turn, are used as a mulching material to conserve moisture around vegetable seedlings in homestead gardens (Begum et al., 1986). Trees also provide support for climbing vegetables, such as bottle gourd and snake gourd.

Livestock x Forestry Interactions. On the subject of multipurpose trees around the homestead, it is interesting to note that certain species of trees are more palatable to some livestock than others. Using the example mentioned previously, jackfruit leaves are preferred by goats more so than by other ruminants (Hussain and Gupta, 1986). While most seedling trees, such as banana, guava, mango and papaya, are easily damaged by grazing livestock, some trees, such as lemon, pomello, wood maple, tamarind and drumstick, are seldom affected (Khan et al., 1986).

Vegetable x Livestock Interactions. Similarly, some vegetables, such as onions, garlic, aroids and bitter gourd, are not damaged by grazing livestock, while others must be protected. Farmers also report that the barnyard manure of different animal species, either alone or in combination with straw, is used for different vegetable crops (Khan et al., 1986). Interactions also exist in the form of tradeoffs of resource allocation on the homestead. For example, scarce water during the dry season can be used either to wash cattle to promote good animal health or to irrigate vegetables, ensuring plant survival and better yields (Hussain and Gupta, 1986).

Fishery x Livestock Interactions. Water hyacinth, which grows profusely in fishponds, lagoons and ditches, is frequently harvested as fodder for ruminant livestock during the dry winter season. Poultry manure is often used as a fish feed in homestead ponds; fish by-products are used to feed poultry. Duckweed from ponds and Azolla spp. ferns from flooded rice paddies are also used as duck feed.

Fishery x Vegetable Interactions. Water hyacinth is also dried in the sun and used as a mulching material for the homestead garden. In an effort to maximize the use of available homestead space, trellis structures of bamboo are commonly constructed over fish ponds to support certain species of climbing vegetables, such as bottle gourd and snake gourd.

Homestead Resource Base x Forestry Interactions. In some cases, simple two-way interactions occur between the different farming strata and technical subsystems. For example, the botanical composition of the agroforestry subsystems on landless farms differs from that of farms with larger landholdings. The pruning management also varies according to resource base. For example, on farms with more homestead space, farmers often attempt to maximize shade; on farms with extremely limited homestead areas, shade is detrimental to vegetable production. Farmers with smaller landholdings and less diversified income sources also tend to plant slower-growing tree species with higher market value for timber on their homesteads as an investment against future cash needs (such as the marriage of a daughter (Hussain and Gupta, 1986)).

Homestead Resource Base x Vegetable Interactions. Strategies for starch staple food production also vary according to the size of the resource base on the farm. For example, farmers with small holdings place more importance on sweet potatoes (Ipomoea spp.) as a starch staple crop than do farmers with larger holdings. Large-scale farmers situate sweet potato crops on low-fertility land, whereas farmers with smaller holdings allocate their highest quality land to sweet potato production (Begum et al., 1986). The vegetables in the diet of farm families also depend on the resource base. For example, more sweet potato leaves are eaten on smaller holdings (Wilson-Moore, 1987).

Homestead Resource Base x Livestock Interactions. As was noted with the agroforestry subsystem, the species composition of the livestock subsystem also varies according to the resource base of the farm. Higher numbers of pigeons and buffalo are found on larger holdings, while goats are more numerous on landless farms (Khan et al., 1986). There is also a tendency to use cows, rather than oxen or buffalo, as draft animals on smaller farms (Saadullah, 1986).

Initial FSR Research on Homesteads

Several attempts have been made to address aspects of homestead production by different FSR teams throughout Bangladesh. Some of these have focused on vegetable seed storage to maintain seed viability by varying the storage container or by applying wood ash and other desiccants. Other studies have evaluated the effectiveness of different farmyard manures on vegetables. However, four of the more promising studies from the standpoint of national application concern the improvement of vegetable production, the use of rice straw as a ruminant fodder, beekeeping and small vegetable and tree seedling nurseries.

Commercial Vegetable Production. A dual-purpose[7] dooryard garden study has been implemented to increase vegetable production on homesteads on several FSR sites. This program involves the use of several vegetables,[8] sequentially planted in beds to maximize land use on the homestead over a 12-month period. It is patterned after the Asian Vegetable Research and Development Center's garden program[9] for Southeast Asia. Multiple planting dates were used to maximize vegetable production over the period. Recent "ex ante analyses" of this project have emphasized monthly vitamin production throughout the year in comparison to the minimum daily vitamin requirements of the farm families involved.

Other gardening projects[10] in Bangladesh have similar designs and objectives. Some of these also involve seed, fertilizer, credit and extension services to specific farmer target groups such as landless farmers and women, while others also have a combined objective of improving gardening, poultry and fruit production on homesteads. However, it must be stressed that in peasant agriculture where farms are extremely small and cultivation depends on highly variable rainfall, the farm family may not be preoccupied with maximizing profits as much as with maximizing their chances for survival. Therefore, homestead-improvement programs must recognize that the homestead garden is inherently subsistence oriented. Wilson-Moore (1987) found that the use of the homestead garden space was significantly greater during the June/July rainy season, when most commercial vegetables cannot be grown.

Treatment of Rice Straw with Urea. With a combined cattle and buffalo population of 177/km^2 (Saadullah, 1986), Bangladesh has one of the highest densities of ruminants per unit of land in the world. However, there is intense competition for limited land, and both crop production for human consumption and forage production for animal feed are important. The result is that the nutrition of the cattle depends, to a large degree, upon crop residues. Land fragmentation in response to human population growth further exacerbates the problem.

Because land is too scarce to set aside for forage crops or pastures, most of the arable land in Bangladesh is in food and fiber crops. The cropping intensity of agriculture averages 154% (Rahman, 1981). Since approximately 77% of the cropland area of the country is devoted to rice production (Saadullah, 1986), rice straw makes up approximately 90% of the energy feed for ruminants. The objective of the treatment of rice straw with a 5% concentration of urea fertilizer and water is to improve the nutritional value[11] and voluntary intake levels of the straw as a fodder for lactating cows.

Beekeeping. As a technology designed specifically for homesteads with limited land resources and few other income-generation options, one FSR team began a beekeeping enterprise. Although this enterprise is still being evaluated in the field, it seems to have potential as a low-cost, high-return investment that requires little space. However, some effort is necessary to coordinate honey production with the seasonal cycles of flowering in plants near the homestead. Current efforts are attempting

to package beekeeping with sunflower production to ensure both a source of nectar for the bees and uniform pollination of the sunflower crop.

Seedling Nurseries. In a similar effort to develop income-generating activities on homesteads with limited resources, seedling nurseries of vegetables, such as tomatoes, eggplants and chilies, and trees, including coconut, betel nut, mango, guava, jackfruit, lychee and papaya, have been encouraged. The area required for such nurseries is minimal, but a source of irrigation and protection from livestock is necessary.

FSR STRATEGIES FOR HOMESTEAD IMPROVEMENT IN BANGLADESH

Once agreement is reached on the need to equate the importance of homestead production with that of other subsystems, it will be necessary to organize a multi-institutional working group for homesteads and to outline procedures for farming systems research on the homestead subsystem.

Institutional Organization

Because of the disciplinary complexity required for farming systems research on the homesteads, a complete multidisciplinary working group with both biological and social scientists is needed. This multi-institutional team will function under the supervision of the Coordination Unit for FSR at the Bangladesh Agricultural Research Council (BARC), which will coordinate homestead studies and serve as a collection center for all information related to homestead development over the long term.

National "Working Group". Since the working group for homestead development will be institutionally affiliated with BARC, it will report directly to National Technical Coordination Committee of BARC.

The "homestead working group" must be a manageable size in terms of number of members, but it must also contain a wide spectrum of academic disciplines. These will include specialists from the following disciplines: agronomy, horticulture, agricultural economics, ruminant and poultry production, forestry, fisheries, anthropology, rural sociology, nutrition and agricultural engineering. The social scientists will be particularly active in spatial mapping in the long-term monitoring of the farms under study to detect adoption levels and technology-diffusion patterns.

The working group will follow standard procedures for farming systems research in Bangladesh, beginning with the design of a diagnostic survey questionnaire. This questionnaire will then be used by FSR teams of all institutions collaborating in the NCFSRP throughout the country to generate national benchmark data on homesteads. The survey will attempt to determine class specificity of resources, felt needs of farmers and long-term investments on homesteads in the different agroecological zones. As such, it will provide the basis for defining national recommendation domains for the homestead subsystem, as well as for targeting production problems within each domain. Indigenous practices

for preventing livestock and plant diseases will also be identified nationally.

After problem prioritization, research trials will be suggested for the respective recommendation domains. Individual FSR teams will then consider the implementation of such experiments according to the FSR priorities established at each site. All homestead experiments will use experimental designs that will allow a T-test comparison of alternative versus farmer practices on neighboring homesteads. Extension personnel will assist in data collection. Data storage, processing, and retrieval will be done on a national level at BARC by members of the Coordinating Unit for FSR.

Interinstitutional Coordination. In order to promote the interchange of ideas and findings among researchers throughout Bangladesh (including workers in integrated rural development projects such as the Comilla Project), BARC will sponsor an annual "national workshop on homestead development." The homestead working group will present a formal report of their activities, findings and work plans at this forum, which will be open to representatives of institutions outside of the NCFSRP. There is a tremendous need to consolidate existing knowledge on homesteads and to provide guidance and direction for future research. One option during these meetings would be to commission papers on new topics for the purposes of workshop discussion.

Procedures Related to Homestead Development

Since the homestead is the focal point for the interaction of other subsystems, disciplines involved in the technical components of livestock husbandry, agroforestry and fisheries will conduct much of their work on the homesteads. After the prioritization of research problems related to the homestead by appropriate recommendation domain, farming systems researchers must distinguish between those homestead activities that are already receiving attention in their region and those that have thus far been ignored.

At present, farming systems researchers in Bangladesh may find that even problems related to agroforestry and livestock have not been adequately addressed due to staffing and training deficiencies at the respective institutes for livestock and forestry research. However, once these staffing and training weaknesses are overcome, farming systems researchers can concentrate on homestead activities unrelated to existing subsystems research efforts. For example, they may begin to focus on subsistence vegetable production (especially during the summer monsoon season, when irrigation is not a production constraint), storage facilities, tree and vegetable seedling nurseries, fruit production, food preparation and other activities that would generate income and improve family nutrition.

Formulation of Recommendation Domains. Khandker (1983) found that in rural Bangladesh there exists a close relationship between farm size, family size, child schooling and income. Therefore, the size of the family labor force (which is related to family size and child schooling rates) is an important determinant of farm household participation in

income-earning activities. Jansen et al. (1983) added that the ownership of land is also an important indicator since the majority of those in rural areas are dependent on income and employment in agriculture.

In an effort to stratify farms according to factors that generate class differences in rural Bangladesh,[12] stratification has been suggested according to four specific target groups: resource-rich households, resource-poor households, landless laborers and women. McCarthy (1981) divided homesteads into solvent, subsistence, poor and extremely poor units.[13] Howes and Jabbar (1986) classified farmers into four categories: big farmer, owner-cultivator, sharecropper and less farmers. Most of the cropping systems research in Bangladesh is based on a classification of producers into landless (less than 0.2 ha), marginal (0.2 ha to 0.5 ha), small (0.5 ha to 1 ha), medium (1 ha to 2 ha) and large (more than 2 ha) farms. Stratification by other criteria, such as proximity to urban markets, family size, income level, land productivity or animal resources, must also be considered.

Focus on Outputs of Homesteads. Not enough information is currently available on the participation of women in income generation on the homestead. However, Hussain and Gupta (1986) identified the fact that women have certain skills (running seedling nurseries, processing date palm juice and making mats from date palm leaves) that could be exploited to generate more income. Likewise, in spite of the lack of land resources, landless farmers were found to own cattle, many of which were rented out for draft purposes. The "share rearing" of goats, in which women share the responsibilities and capital investment, was also noted as a means of generating cash income where resources would otherwise not permit.

The use of indigenous rainy-season vegetables to satisfy dietary requirements to subsistence producers deserves special attention. Future surveys need to identify the sources of risk (uncertainty) for each subsystem, period of food shortages during the year and variation of food prices. Farmer response to this risk and to periods of food shortages can be monitored by the sale of trees and livestock to generate cash for food purchases.

Operational Constraints: FSR and the Homestead

Institutional Constraints. The characteristics of institutions differ in Bangladesh, depending on the history, resources, political status, relationship with international aid agencies and international agricultural research centers, overseas training of staff and mandate of each institution. This fact compounds the difficulties related to interinstitutional coordination in a national FSR program with numerous member institutions.

Several of the institutions involved in FSR in Bangladesh have a specific crop mandate. Expanding the activities of these institutions into homestead improvement will be difficult. However, cooperation is possible and has been somewhat successful in the past. For example, BRRI devised a cropping pattern involving two sequential rice crops with

improved short-duration rice varieties. BARI then worked out the most appropriate fertilization rates for this entire cropping pattern, rather than for maximum economic returns from individual crops in the pattern. A similar inter-institutional memorandum of agreement was developed between BARI and DAE in which female extension personnel were assigned to work with the BARI homestead case studies for 1 year.

Only 320 out of 9,880 block supervisors in the Department of Agricultural Extension are women. Few, if any, of these female block supervisors have received training in production technologies or FSR methodology.[14] Most of their academic preparation has been in the areas of nutrition, sanitation and home economics. A serious effort to generate and transfer new production technologies for the homestead may require an increase in the number of well-trained female extension personnel.

Disciplinary Constraints

Many of the FSR sites in Bangladesh are not staffed with complete multidisciplinary teams because of disciplinary weaknesses on the part of the NCFSRP member institutions. Much of the conceptualization of FSR methodology for specific subsystems has been left to each member institution of the NCFSRP. Furthermore, guidelines for data-collection procedures have not been developed to standardize FSR operations on a national basis. Technical support from NCFSRP member institutions for a strong, balanced, national homestead-research program will be limited by these disciplinary weaknesses in the immediate future, especially in relation to subsistence rather than commercial farm-management strategies.

Potential Interventions for the Future. Given the disciplinary complexity of the homestead subsystem, the decision on where to direct FSR resources initially can be confusing. Poultry specialists will argue for attention on poultry-disease prevention, while fishery specialists will argue for improved fish-culture technologies. However, based on available literature on homesteads in Bangladesh, the following issues appear universally problematic.

The excessive labor demands on women during the post-harvest processing period suggest the need for attention to the identification of appropriate labor-saving technologies. However, Ahmed (1983) pointed out that post0harvest processing equipment is difficult to justify economically in Bangladesh because of the low cost of female family labor and the low level of post0harvest losses in hand processing. Even small-scale driers proved to be uneconomical, but hullers seemed more feasible because they increased labor productivity and were cheaper than hiring manual labor for the same purpose, depending on the proximity of the rice mills to the homestead and the resultant transportation costs. Special-purpose surveys should also concentrate on the issue of labor reciprocity within extended families and villages and on farmer "felt needs" in the area of new technologies.

Considerable effort continues to be extended in Bangladesh to increase cropping intensity for field crops. Theoretically, this should result

in a proportional increase in the amount of crop by-products available as ruminant feed. However, studies are needed to provide information that would result in improved management practices, ensuring a balance between the quality of by-product livestock, feeds and crop yields. Techniques involving better water management could also enhance crop and livestock production by extending the growing season of crops into the dry season. On those farms where rice straw is currently being burned as fuel, more fuel-efficient stoves could reduce the fuel demand, thus making the rice straw available as a ruminant feed (Nielsen and Preston, 1983).

In addition to furthering the commercialization of the homestead garden, efforts should be made to improve subsistence vegetable production, especially during the summer rainy period. More information is needed concerning periodic food shortages throughout the year. Vegetable varieties could be selected to fill these gaps and to supply minimum daily requirements of essential nutrients.

Since space is limited, techniques to maximize sunlight interception through multistoried gardening should be explored. Constructing trellises over ponds and using fences as trellises would also extend the cultivation acreage for climbing vegetables such as gourds and beans. Priority should be given to vegetables, which supply the limited vitamins and minerals in family nutrition and which are moderately shade tolerant. The sale of vegetable seedlings might serve the purpose of increasing income for landless farms while encouraging better horticultural practices on homestead gardens.

Local livestock breeds can best tolerate scavenging for food, and improving local breeds is illogical until the food supply is improved. Current research to improve the nutritional quality and digestibility of rice-straw fodder through treatment with urea and lime should be expanded on a national basis. Since most of the rice straw from the "Aus" rice crop at the very beginning of the rainy season rots at the beginning of the monsoon season, preservation and storage of "Aus" rice straw should be given priority. The incorporation of more nutritious winter-season forage species into existing cropping patterns (such as the relay intercropping of forage legumes in rice fields, which are nearing harvest) should also be tested. Other studies on optimal management practices for cows used for both draft and milk production should be undertaken.

Sociological research is needed to determine local perceptions on the usefulness of different tree species. Research on identifying and introducing well-adapted, fast-growing firewood species to relieve the constant need for fuel should be encouraged. More fuel-efficient stoves may also reduce demand for firewood. Optimal pruning management of existing trees for firewood and fodder and to allow light penetration for vegetable gardening requires further investigation. Dwarf tree species may offer an option if firewood and fodder production are not sacrificed. Fruit trees, especially those containing substantial quantities of vitamins A and C, such as papaya and citrus species, offer possibilities to improve family diets through the forestry subsystem.

SUMMARY: FACTORS REQUIRED FOR FSR ON HOMESTEADS

If the Bangladesh experiences of incorporating the homestead into the realm of FSR can serve as a model for other countries, several activities must be undertaken. These include the following:

Justification of the Homestead Subsystem

Before a serious effort can be made to improve homestead production in any country, people must recognize the importance of homesteads in family nutrition and income generation. Policy-makers must also recognize the opportunity that homestead development presents for improving the welfare of landless farmers and women in society. Until the homestead production unit is given equal status with other subsystems, only isolated token efforts at homestead improvement can be expected, and FSR will remain incomplete.

Assignment of Institutional Responsibility

The first question to be addressed concerns the delegation of institutional responsibility. In the case of Bangladesh, no single member institution of the NCFSRP was equipped to fully staff a multidisciplinary "homestead task force." For this reason, national leadership was assigned to BARC, which was given responsibility for organizing a multi-institutional working group and conducting an annual "homestead improvement workshop." The first task of the homestead working group will be to develop a diagnostic survey questionnaire to be enumerated on homesteads at all FSR sites in the country. Subsequent data analysis and planning of recommendation domains will then be carried out by the working group. Annual national workshops on homestead development provide the mechanism for the exchange of information with other government and nonprofit, voluntary organizations.

Development of a FSR Methodology for Homesteads

The application of FSR methodology to the homestead requires that attention first be given to formulating recommendation domains through an analysis of agroecological and socioeconomic factors. In the process of this national diagnostic study, specific production constraints and major subsystem interactions can be identified. Initial problem prioritization by recommendation domain is then possible. Once such baseline data is available, individual FSR teams can obtain more detailed information through special-purpose surveys, upon which work plans specifically directed to homestead improvement can be developed.

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END NOTES

[2]The institutions are the Bangladesh Agricultural Research Institute (BARI), Bangladesh Agricultural University (BAU), Bangladesh Jute Research Institute (BJRI), Bangladesh Livestock Research Institute (BLRI), Bangladesh Rice Research Institute (BRRI), Forestry Research Institute (FRI) and Sugarcane Research and Training Institute (SRTI).

[3]Some plant combinations are used for specific purposes. For example, arjuna (Arjuna indica) bark and haora leaves are mixed with goat milk for treatment of dysentery, while haora leaves alone are used to treat hoof-and-mouth disease in cattle.

[4]This operation normally involves a foot-driven threshing device called a "dheki," which is not found on all homesteads.

[5]Women can nurse children while parboiling rice or carry a child while stirring rice on the drying floor with their feet (McCarthy, 1981).

[6]Some studies suggest that the number of bullocks on a given farm is directly proportional to the amount of rice straw and pasturage available (Magor, 1986).

[7]To provide the vitamins lacking in family nutrition and to generate income through the sale of seasonal surpluses.

[8]These include indian spinach (Basella alba), date (Amaranthus lividus), tomatoes, okra, bittergourd (Momordica charantia), batisak, tasaki mula radishes (Raphanus sativus), coriander, eggplants, turmeric, chilies and knol knol (Brassica oleracca).

[9]The home garden is designed to be culturally acceptable and supply the needs for a family of five (Gershon, 1985).

[10]Sponsored by organizations such as the Mennonite Central Committee, CARE, Helen Miller International Adventist Development and Relief Agency and Oxfam.

[11]Refers more specifically to the dry matter digestibility and crude protein content of the fodder.

[12]These include differential ownership of land and access to resources such as technical inputs, credit and irrigation.

[13]Farmers on solvent homesteads are able to satisfy their family needs and generate an agricultural surplus for marketing through a combination of farming and off-farm employment.

Farmers on subsistence homesteads obtain less than one-half their income from off-farm employment but are incapable of generating an agricultural surplus for marketing.

Those who live on poor homesteads are small-scale traders, rickshaw pullers and day laborers who purchase most of their starch staple food.

Those who live on extremely poor homesteads are without a regular source of income through employment outside the homestead. However, the women in this classification do generate some income by processing rice for other villagers on their homestead; men work as day laborers and are paid in kind or with meals.

[14]The training of male extension personnel in FSR methodology has also been inadequate: only 16 subject matter officers have been trained thus far for 25 FSR sites and over 80 multilocation testing sites.

APPENDIX A

MAJOR HOMESTEAD TREE SPECIES IN BANGLADESH

Fruit		Timber	
Mango	(*Mangifera indica*)	Mango	(*Mangifera indica*)
Jackfruit	(*Artocarpus* spp.)	Teak	(*Tectonia grandis*)
Lemon	(*Citrus lemon*)	Jackfruit	(*Artocarpus* spp.)[2]
Custard apple	(*Anova squamosa*)	Coconut	(*Cocos nucifera*)
Banana	(*Musa sapientum*)	Rendi[1]	(*Samanea saman*)
Litchi	(*Litchi chinensis*)	Koroi[1]	(*Albizia* spp.)
Blackberry	(*Eugenia jambolanum*)	Neem[l]	(*Azadirachta indica*)
Betel nut	(*Areca catechu*)	Pitraj[l]	(*Amoora rohiturka*)
Amra[1]	(*Emblica officinalis*)	Kapok	(*Bombax malabaricum*)
Papaya	(*Carica papaya*)	Bamboo	(*Bumbusa vulgaris*)
Guava	(*Psidium guyava*)		
Elephant apple	(*Feronia elephantum*)	Firewood[3]	
Carambola	(*Averrhoa carambola*)		
Pomello	(*Citrus decumana*)	Mandar[1]	(*Erithryna* spp.)
Wood apple	(*Aegle mermelos*)	Shimul[1]	(*Salmalia malabrica*)
Tamarind	(*Tamarindus indica*)	Jarul[l]	(*Lagerstoremia* spp.)
Date palm	(*Phoenix dactylifera*)	Hijal[1]	(*Barringtonia acutangula*)
Jujube	(*Zizyphus jujuba*)	Acacia	(*Acacia nilotica*)
Jaam[1]	(*Eugenia* spp.)	Jhiga[1]	(*Lanula coromandelica*)
		Sheora[1]	(*Streblus asper*)
		Shojne[1]	(*Moringa oleifera*)
		Bay leaf	(*Cinnamonum tamala*)

Source: Camacho, 1986; Wilson-Moore, 1987; Hussain and Haque, 1986; Khaleque, 1987.

[1]Common names are in the local Bangla language.
[2]Only ungrafted jackfruit trees are used for timber. Farmers reported that grafted trees are not well suited for timber (Hussain and Gupta, 1986).
[3]The twigs and leaves of all homestead trees are used as firewood. In general, trees have a greater commercial value as fuel on farms near brick-making kilns (ovens).

APPENDIX B

HOMESTEAD VEGETABLE SPECIES

Gourds and Squash	
Snake gourd	(*Trichosanthes cucumerina*)
Bottle gourd	(*Lagenaria vulgaris*)
Wax gourd	(*Benincasa cerifera*)
Ribbed gourd	(*Luffa acutangula*)
Bitter gourd	(*Momordica charantia*)
Pumpkin	(*Cucurbita moschata*)
Cucumber	(*Cucumis sativus*)
Leafy Vegetables	
Indian spinach	(*Basella alba*)
Amaranthus	(*Amaranthus* spp.)
Helencha	(*Enhyra flactuans*)
Taro	(*Coloscasia* spp.)
Betel leaf	(*Piper bettle*)
Jute leaf	(*Corchorus capsularis*)
Others	
Eggplant	(*Solanum melongena*)
Tomato	(*Lycopersicon esculentum*)
Country bean	(*Dolichus lablab*)
Roots and Tubers	
Potato	(*Solanum tuberosum*)
Sweet potato	(*Ipomoea batatas*)
Spices	
Ginger	(*Zingiber officinale*)
Tumeric	(*Curcuma domestica*)
Green chili	(*Capsicum annum*)
Onion	(*Allium cepa*)
Garlic	(*Allium sativum*

Source: Adapted from Wilson-Moore, 1987.

APPENDIX C

PERCENTAGE DISTRIBUTION OF LIVESTOCK BY SIZE OF HOLDING IN TWO DISTRICTS OF BANGLADESH (1984)

Category[1]	Households	Bullocks	Cows	Calves	Goats
	(%)				
	Noakhali District				
Landless	43.2	0.0	6.0	16.5	32.7
Marginal	15.1	2.8	16.9	12.2	20.4
Small	16.4	17.4	25.9	13.2	11.2
Medium	14.5	39.6	29.5	27.5	24.0
Large	10.7	40.3	21.7	30.8	9.7
Total	100.0	100.0	100.0	100.0	100.0

Category	Cattle	Buffalo	Goats	Poultry	Ducks	Pigeons
	(%)					
	Jamalpur District					
Landless	10.0	0.0	10.1	14.8	6.3	0.0
Marginal	17.5	0.0	28.8	18.7	17.5	0.0
Small	18.8	0.0	20.2	15.6	4.8	7.4
Medium	21.3	26.3	24.1	23.3	50.8	18.5
Large	32.5	73.7	22.8	27.7	20.6	74.1
Total	100.0	100.0	100.0	100.0	100.0	100.0

[1]The farm sizes for each category are as follows: landless <0.01 acres; marginal 0.01-0.5 acres; small 0.51-1 acres; medium 1.01-2 acres; large >2 acres.

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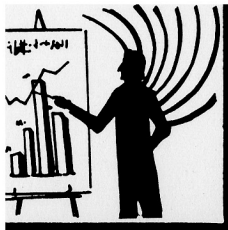

Information and Communication Systems

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INFORMATION AND COMMUNICATION SYSTEMS

Farming systems research and extension (FSR/E) methodology offers an innovative scheme for information management. It provides a framework to adapt and strengthen traditional research-extension-academic roles while drawing the farmer and the farm family into the decision-making process of agricultural development. Thus, the FSR/E approach, per se, is designed to develop, process, analyze and relay information.

In their papers, authors have identified the need for developing human resources by enhancing individual, team and institutional communication skills and links. They discuss their research, the results of which must be communicated to decision-makers who use, or ignore, this information to formulate policy. As the farming systems body of knowledge becomes more accurately defined and documented, it will be complemented by the further development of systematic processes, and new informational methodologies will arise. Using past methodologies, we have recognized the need to include information and communication specialists on the multidisciplinary team at certain stages of the process. This team has traditionally consisted of agricultural economists, agronomists and animal scientists and has only recently broadened to include rural sociologists and anthropologists.

As more information is created and(or) entered online, the analysis and value of agricultural data at all levels of decision-making increases. Expert systems are just one example of what computerized information systems offer the FSR/E researcher. As cautioned by some authors, any knowledge system must take into account the indigenous agricultural knowledge systems of both technology nonadoptors and adoptors alike. Even today, the literature clearly indicates that technology relevant to the user remains lacking, while researcher-based technology generation continues to lack the linkages necessary to move that technology to the user.

In the years ahead, agricultural communicators and information specialists will continue to address the issues of institutional structures, such as extension and research linkages, and to chronicle how the FSR/E body of knowledge has contributed to agricultural information systems, which are in fact technology-transfer systems.

Raymond Barclay, Jr., Co-chair
Gretchen Graham, Co-chair

DAVID W. NORMAN

David Norman is one of the pioneers of the ever-evolving farming systems approach to research and extension. Born and educated in England, he worked as a farm laborer in Sussex, England, and Tyrol, Austria, and studied at Wye College, University of London. He continued his studies in agriculture at Toronto University and received his advanced degrees in agricultural economics at Oregon State University.

After spending three years as a research fellow at Ahmadu Bello University, Zaria, Nigeria, David began employment with Kansas State University, becoming a professor. He was named head of the Department of Agricultural Economics and Rural Sociology at Ahmadu Bello in 1973 and remained in that post until 1967 when he returned to Kansas State to teach agricultural economics from 1976 to 1982. He has 22 years of experience in his discipline and 17 years of overseas experience.

His publication record began in 1964 while he was at Oregon State University. A prolific author and speaker, he has contributed to numerous journals, books, conferences, seminars and workshops throughout Africa, Asia, the Middle East, Latin America, Europe and North America.

Among his many contributions to the scientific body of knowledge are applying agricultural economics to African farming systems, sensitizing agricultural economists to work in U.S. Farming Systems Research and Extension Symposiums and graciously opening his personal research files to students and researchers worldwide. This collection is located in the resources-on-developing-countries unit of Farrell Library at Kansas State University.

Today, he is chief of party for the Agricultural Technology Improvement Project, Sebele, Botswana, where he, his wife Linda, and daughter Traude, currently live. Two sons, Ian and Andrew, attend universities in Kansas.

COMMUNICATION AND INFORMATION SYSTEMS IN FARMING SYSTEMS WORK: AN OVERVIEW

D. W. Norman[1]

INTRODUCTION

Initially I was delighted when invited to give a plenary paper at this symposium, especially because I have been unable to attend these meetings since the first one in 1981. Then, when I sat down much later to write something, I realized to my dismay that I really know very little about the subject that probably would be of value to an audience such as this. After a couple of days reading about the subject and thinking about my own lack of formal training in communication and information systems, I decided to be pragmatic and consider the subject in terms of the farming systems practitioner in the field.

As I look back to the late 1960s and early 1970s when many of the tenets underlying farming systems work were coming together, I think many of us were still very discipline "blinkered," sometimes arrogant in our thinking and certainly simplistic in our thinking about the process of change. The farming systems approach was, and is, conceptually sound, but its very simplicity and internal consistency fooled some of us into a false sense of security that it would be readily accepted. Obviously we were wrong, although it has, of course, had considerable popular appeal. Like so many concepts, its implementation has not always been easy. There are many reasons for this, some of which are location specific, but on reflection it seems to me a number of these could have been reduced or eliminated through better communication and information-transfer systems.

As Bemis et al. (1987) point out in their paper, communications technology has seldom been designed and tested successfully. Instead, expertise in communications in farming systems projects is often assumed as coming from previous training and on-the-job experience. Certainly I confess I did not start seriously thinking about this as an explicit issue until mid-1986 when our project was subjected to its second external evaluation. At this time the issue of developing stronger links with extension and planning was emphasized. Obviously improved communication and information systems can help in bringing this about.

That is enough in the way of a confession! What I have tried to do in this paper is to address very briefly the communication and information channels that farming systems projects need to address to be effective, ways of encouraging this, the types of communication and information that are required, progress that has been made and challenges that are remaining. Since this is an overview paper and other people are more qualified to speak on specific topics, I will not dwell much on detail but, when relevant, will reference other work — including papers presented at this symposium. The perspective I will be using is that of

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[1]Agricultural Technology Improvement Project, Department of Agricultural Research, Ministry of Agriculture, Gaborone, Botswana.

a team leader on a farming systems project, working in a low-income country.

CONTRIBUTORS TO AGRICULTURAL DEVELOPMENT

It has long been recognized that there are four groups of actors contributing to the process of agricultural development: farmers, extensionists, researchers and policymakers (planning/development). However, with the advent of farming systems work, the one-way "top-down" pattern depicted in Fig. 1, so characteristic of many low-income countries, was to some extent replaced by that in Fig. 2, where on-farm research — done by farming systems teams — has attempted to create a "bottom-up" perspective. In this approach two-way linkages are emphasized rather than the single direction of earlier days. The two-way linkages are important between all the actors in the process of agricultural development. Unfortunately some of these linkages tend to be fragile. From the practitioner's viewpoint, the relative strengths of these linkages tend to be those shown in Fig. 3. Why does this occur? Can improved communication and information systems help overcome this?

In terms of the former question, some of the problems that often contribute to this situation revolve around the following (Poey, 1986; Fresco and Poats, 1986; Gilbert et al., 1980):

Educational elitism. Differences in the level of formal education tend to inhibit productive dialogue. This is manifested in a number of ways. For example, researchers have often regarded farmers of limited value in making useful contributions to the technology-development process. Also researchers have regarded extension workers — who in low-income countries usually have poorer academic qualifications — in somewhat the same light. Finally, policymakers, because of their dominant position in many government bureaucracies, have acted somewhat independently of the other participants in the agricultural development process.

Maintaining the status quo. Farming systems projects have often been viewed as a recipe for overcoming failure. As "newcomers on the block," they are often viewed with a good deal of suspicion by other actors in the agricultural development process who have been around much longer. Quite understandably, most of the other actors have vested interests in maintaining the status quo and consequently regard farming systems workers as a threat rather than as partners. This is particularly true in the case of the people in the department in which such projects are institutionally located. This also tends to be the case when projects involve strong donor agency input of funds and personnel. The desire to maintain the status quo is further strengthened when limited resources are available after external funding dries up. In such a case, if the domestic-resource pie is not increased to absorb such types of work, other actors in the agricultural development process could be adversely affected.

Institutional rigidity. In many low-income countries, agricultural research, extension and planning are separated into different

administrative units (for example, divisions, departments, ministries). Sometimes even livestock, and crops are separated into different administrative units (Abalu and Raza, 1986). Since budgets and personnel relate to specific administrative units, there is vertical control, discouraging the horizontal links that are necessarily implied in the interactive nature of the various groups in the agricultural development process. As far as farming systems projects are concerned, the strongest links are obviously within the institution in which they are located. In many countries this tends to be within the research organization. Indeed, I have assumed this in Fig. 2 and 3. However, analogous arguments do prevail if farming systems projects are in another administrative unit. However, effective farming-systems-type work requires that links be established and maintained.

Evolving methodology. I believe that farming systems work gained too much popularity too quickly. Many methodological issues for undertaking farming systems work are still being resolved. For outsiders, particularly for station-based researchers and planners, this does not look good. Indeed, many of them appear to regard farming systems work as more of an art than a science. Even within a country, different farming systems projects sometimes have different approaches. This is not necessarily unhealthy, since farming systems work by its very nature is location specific, but it can contribute to reduced credibility as far as outsiders are concerned.

Lack of expertise. Lack of national staff available and trained in appropriate techniques obviously creates problems and needs no further discussion.

In the above discussion I have deliberately used the word "project." This word has specific connotations for many people in low-income countries. Often it implies donor-agency involvement and, to a greater or lesser extent, implies control of funds and personnel. By its very nature, a donor agency is concerned with quick results from its contributions. Therein lies the nature of the problem. Many of the problems listed above will take time to solve (Lev, 1986), but donor agencies for obvious legitimate reasons give little time. Thus team leaders on such projects face a dilemma. There is no way that changes can be legislated in such situations. What is required is the winning of people's hearts and minds. There is little doubt that this will take time. I believe that, given enough time, appropriate communication and information systems can help overcome some of the barriers or problems listed above and thereby strengthen the weak linkages in Fig. 3.

However, in the time equation, another factor that can be considered is the level of resources that are used to develop or strengthen the linkages. Some argue that use of large amounts of resources now could quickly break down some of these barriers. However, others argue that massive inputs of donor-agency funds would encourage criticism and have little constructive payoff in the long run. The same individuals are also likely to argue that, in the interest of leaving something viable in place after the departure of donor support, levels of input should approximate that which the host government can sustain in the long run.

Once again, there is a difficult trade-off as far as most team leaders of donor-funded projects are concerned.

I suppose decisions on such matters come down to personal biases. My own bias is that I believe longer time frames are required than most donor agencies would be comfortable with. I believe that, in order to get farming systems work enthusiastically accepted within most national settings, time is required. I also believe it is important to avoid being overly critical of an existing situation, particularly in the early days, until credibility, mutual trust and respect have been established and also that it is important to work within the existing organizational structure (Rawson and Grosz, 1986). In addition, it is important to strive for an operational system that can be sustained after donor funding dries up — as indeed is currently happening in many countries. Resources from donor agencies can now be used to create the conditions necessary to sustain such programs in the future (e.g., trained staff). Also I believe many farming systems projects, including ours, can productively spend more money in setting up communication and information systems that facilitate the development of good links.

The desirability of trying to work within the institutional structure that exists may appear to be unnecessarily constrictive, since the ideal structure for incorporation of farming systems work is unlikely to exist. There are relatively few examples — notable exceptions are Guatemala (Hildebrand and Kearl, 1986) and Zambia (Eylands et al., 1986) — where a decision was made at top governmental levels to reorganize agricultural institutions to incorporate farming systems work. Thus most farming systems projects are working in imperfect organizational situations for which Collinson (1986) had delineated less radical options for incorporating farming systems work. Thus communication and information systems become even more significant in overcoming the negative characteristics of most existing institutional structures.

I want now to turn to a discussion of some of the links specified in Fig. 3. These links are as follows:

- farmer/farming systems workers
- farming systems workers/station-based researchers
- farming systems workers/extension personnel
- farming systems workers/planners and development specialists

Before discussing these in detail, I will discuss briefly two other areas that are important in terms of communication and information exchange. These are the desirability of having overall coordination of farming systems work and communication within farming systems teams.

OVERALL COORDINATION

The challenge is to provide greater coordination between farming systems work and other institutions involved in agricultural development. Such links need to be established and, as a result, have the potential for improving communications and thus improving the effectiveness of farming systems work. The problem of such coordination is that it can be

perceived by administrators in government institutions as a takeover bid by farming systems teams.

Possible strategies to overcome this lack of overall coordination are many. At the very least, farming systems workers need to meet to exchange experiences — something we are currently doing in Botswana. The next step in widening the impact is to provide information to existing national committees, usually through the department in which the farming systems teams are located (e.g., research). A more visible approach is to employ a national coordinator of farming systems work, as is the case in Zambia (Eylands et al., 1986). Such a coordinator can help in accessing policy-making groups, a point that is stressed by Zandstra (1987), as well as provide links between research and extension and between station-based research and the farming systems teams. There is no doubt that a coordinator or a steering group composed of research, extension and planning representatives can facilitate or improve the potential impact of farming systems work. In most countries, however, this is not immediately possible and requires work.

TEAM HARMONY

The challenge is for farming systems teams to operate in an interdisciplinary rather than a multidisciplinary manner. Team members must have compatible personalities, confidence in using the analytical tools of their own disciplines and a healthy respect for the role of other disciplines. They must be wiling to be team players (Norman et al., 1982). And above all, as Rincon (1987) has pointed out, they must be able to listen, understand and accept other viewpoints, and be prepared to modify their own views. There are many obstacles to this idealistic situation, as Knopp et al. (1986) have pointed out, not the least being the lack of professional rewards in terms of salary, etc., as far as interdisciplinary work is concerned. Special problems can arise on donor-funded farming systems projects that have both local and foreign representation. Moussie (1987) indicates that such problems can be surmounted to some extent through sondeo-type activities where local researchers obviously have a comparative advantage, thereby providing an opportunity for establishing their credibility.

In an ideal situation, it would obviously be desirable for the team leader to choose the team members. Important strategies that can help create the basis for harmony are holding frequent and open conversations in formal and informal settings (Esslinger and McCorkle, 1986), striving for relaxed situations in which dialogue can take place and producing multi-authored papers. Thus communication and information systems are definitely important in fostering harmony within farming systems teams — something that we tend to forget when we are busy with field work.

FARMER/FARMING-SYSTEMS-TEAM LINK

In the late 1960s, technical and social scientists of many disciplines realized what sociologists and anthropologists already knew, namely that

farmers were communicators who could contribute substantially to the identification, development and evaluation of relevant improved technologies. That realization provided the major impetus for advocating the farming systems approach. The challenge still stands as to how such farmer participation can be made truly effective.

I submit that, even though we have preached farmer participation, we often are not good at ensuring that it takes place. In this sense I agree with the general tone of the recent workshop on farmer participatory research held at the University of Sussex. A lot has been learned in recent years on this (see, for example, Farrington and Martin, 1987; Ashby, 1987; Ruano and Calderon, 1982; Youmans, 1986; Sigman and McArthur, 1986; Fernandez and Salvatierra, 1986; Cook, 1987; Miller et al., 1987). Still, as Galt and Mathema (1987) rightly point out, shorter and more cost-effective ways of including farmers in the research process need to be found. In an effort to address this, one of the methods we are trying extensively at the moment is the use of different types of farmer groups (Norman et al., 1987).

Sondeos, farmer-implemented and sometimes farmer-designed trials, farmer field days and workshops, etc., have all become part of farming system programs. Indeed, there is little doubt that there has been a move, justifiable in many cases, away from the "hard" data syndrome characteristic of some -early farming systems work to the "soft" data bias that tends to be more popular now. Emphasis on verbal communication has increased. However, how many of us have received tips on how to speak with farmers in a constructive, productive and egalitarian manner? I suspect not many of us who are technical scientists or agricultural economists. Obviously many of us need help with respect to this.

Three of the major issues we need to resolve are:

"Hard" or "soft" data. As Galt and Mathema (1987) indicate, the objectives and use of data determine the frequency, intensity and method of data collection. "Soft" data, often qualitative and essentially "subjective" in nature, is less amenable to statistical analysis than is more expensively collected, quantitative and therefore "objective" hard data. For farmers, soft data are likely to be more influential, embedding information in their own terms of reference. For example, Durant and Christy (1987) found that subjective attributes of the technology were a major factor in its adoption by farmers. However, for encouraging links between farming systems teams and station-based researchers, planning/development staff and possibly extension staff, hard data are likely to be a lot more convincing. Therein lies the dilemma. Concentrating on farmers alone does not facilitate development of other links important in the farming systems process. Thus, in practice, a judicious mix of the two usually is desirable. Fortunately, with the advent of microcomputers, either soft or hard data can be and should be entered and, whenever possible, analyzed and made easily accessible to other interested people. This revolution in microcomputer technology greatly facilitates the dissemination of data from farming systems projects.(It also makes standardized analysis simple and quick (Zandstra, 1983)).

Units of analysis. How to define the unit of analysis (e.g., should it be family or household or supra-household — where resources are shared, etc.) continues to be a contentious issue (Caldwell, 1984; Behnke and Kerven, 1983). The same dilemma applies as with soft and hard data. What might be suitable as far as farmers are concerned might be different from what planners use.

Gender issue. The debate over inequitable participation of male and female farmers in the research process, and in accessing the fruits of such work, justifiably continues. Many have written on this issue, and still it needs to be resolved (Spring, 1986; Hahn, 1986). Communication channels have to be established with, and information collected from, disadvantaged female farmers to ensure that abuses do not occur. Increased sensitivity on the part of many farming systems teams concerning this issue is required.

FARMING-SYSTEMS-TEAM/STATION-BASED-RESEARCH LINK

While all of us recognize the complementary nature of on-farm research (farming systems teams) and on-station research (station-based research), the challenge is to make the two-way linkage effective. In general, station-based researchers have found the link from them to the farming systems teams'(which select technologies off the shelf) less threatening than the link in the opposite direction (in which farming systems teams help determine on-station research priorities)(Schulman, 1983).

Such attitudes are further aggravated by the fact that farming systems teams often consist of individuals who have lower academic qualifications and, as indicated above, often collect data "soft" in nature. This is sometimes explicitly encouraged through nonformal experimental designs in which farmers play a significant role (Lightfoot, 1986). However, even when an attempt is made to use standard experimental designs, assumptions and ceteris paribus, conditions are often violated, resulting in unacceptably high levels of variation in terms of results.

Such situations often lead to statements about the experimental work being sloppy, implications concerning lack of technical expertise on teams (Lev, 1986), etc. Undoubtedly these criticisms sometimes have some validity, but the severity of the problem can be reduced through greater contact (communication and information exchange) between the two groups of researchers. Obviously this is easier when both are housed in the same administrative unit. Ways in which greater contact can be facilitated are through encouraging station-based researchers to visit the farmers' fields, to participate in farm field days and, when feasible, to engage in collaborative research (Norman and Baker, 1986). Annual meetings at which results from the previous year's work and plans for the next year's work are presented for discussion and approval can also be important elements in bringing about better contact.

In recent years, the introduction of microcomputers and programmable calculators has been important in facilitating in-site data management

and analyses (Ranaweera and Gonzaga, 1987). Such innovations have enormous potential for improving timely exchange of information between on-farm and station-based researchers. We have found that using different series and numbering systems on documents written and distributed can be very useful when keeping track of such information, which may be either provisional or final. Computerized mailing lists can facilitate making this information available to a wider audience.

Although a great deal of attention has in recent years been given to devising appropriate methodologies for undertaking on-farm research, Byerlee (1986) has noted that very few guidelines have been developed for efficiently summarizing and synthesizing information generated by such work, which can be approved by research for transmission to extension and farmers. Usually, large amounts of data are condensed into a single package or "recipe" of improved technology. Byerlee (1986) argues that a greater return can be made from invested research resources. According to him, the challenge is now to synthesize the most important findings to simplify them in a way that can be readily understood by extension staff and farmers, to develop recommendations (prescriptive information) and to give extra guidelines (auxiliary information) to help extension staff and farmers adapt the recommendations to their own circumstances. Auxiliary information has not traditionally been used in recommendations drawn up in many low-income countries. Such information places special demands on researchers in tailoring recommendations to the realities of the farmer's environment and on the extension staff in moving to more of an educational role, as opposed to the more traditional approach of simply communicating messages.

FARMING-SYSTEMS-TEAM/EXTENSION LINK

In retrospect, it is unfortunate that, in the early days of farming systems work, the critical link with extension was not better appreciated. Abbott and Mundy (1986) in fact found that farming systems personnel attending last year's symposium felt that the lack of communication between research and extension was the most serious communication problem. The challenges are to overcome the image of extension work staff as junior partners to researchers (Sowers and Ousseini, 1987) and to devise ways in which they can be involved at all stages of farming systems work (Kellogg et al., 1984; Poey, 1986; Chamala and Keith, 1986) and not just at the dissemination stage, as some of us used to advocate. The extent to which this is practical would depend, of course, on factors such as the attitudes of supervisory extension personnel, other work commitments, incentives (Worden and Ludgate, 1987), etc. Nevertheless, such commitments at the local level, although desirable, do not have to be great to defuse lingering fears in extension staff minds of farming systems personnel invading their turf and taking over their jobs. Improved communication between extension and farming systems staff can open up possibilities for constructive suggestions from extension while at the same time providing such staff with opportunities for their own evaluation of technologies that later may be recommended. Minimum levels of contact involve encouraging their leadership in village-level meetings and farm field days at which work

plans and results of farming-system-team work are discussed and displayed.

In addition, the value of such contracts can be strengthened, usually from the headquarters level, through newsletters giving information on farming systems work, continual updating of recommendations particularly through the inclusion of more auxiliary information, provision of jargon-free abstracts of research reports and continuing in-service training of extension staff. For example, in Botswana there is a farming systems page in a monthly newsletter produced by extension that is distributed widely among government officers. Researchers are actively involved in writing recommendations, subject-matter specialists are now writing extension leaflets of various kinds, and farming systems personnel are involved in a major in-service training program for extension staff.

In many countries increasing the academic qualifications of subject-matter specialists at headquarters and regional levels is particularly critical in establishing collegial relationships with researchers and in helping them to increasingly take over responsibilities for some of the activities listed above. As an interim aid in the process of developing this expertise, a compromise strategy is often implemented. This involves the appointment of research extension liaison officers, usually at the headquarters or sometimes at the regional level (Eylands et al., 1986).

Desktop publishing systems with the aid of microcomputers have provided a relatively cheap, revolutionary technology for facilitating the distribution of information, including training materials. Recently such a system has been purchased in Botswana for use by the extension service. What still is required, in many cases, on the part of both the subject-matter specialists and the researchers in farming systems teams are skills in writing materials that can be easily understood by extension staff. In Botswana we are using a short-term consultant for this purpose. Collaborative writing on the part of researchers and extension staff would be an ideal to strive for in many situations.

FARMING-SYSTEMS-TEAMS/PLANNING-AND-DEVELOPMENT LINK

It is generally recognized that designing and disseminating relevant, improved technologies and policy/support systems are equally important in increasing the productivity of farmers. Nevertheless, until recently, most farming systems work has treated policy/support systems as parameters not amenable to adjustment. Perhaps one reason for this has been the leadership role played by the international agricultural research centers in developing and disseminating the farming systems approach. Because of their mandates, they were earlier reluctant to address policy/support systems that often were location specific and usually had political connotations. Although farming systems teams operating within national programs have long recognized the desirability of treating policy/support systems as variables, they have not had the expertise, clout or channels to do it. (However, for exceptions to this, see work done in some Francophone countries, such as Mali and

Senegal (Verbeek et al., 1986; Fresco and Poats, 1986)). Indeed, the challenge remains as to how the bottom-up orientation of farming systems work can constructively influence the designing and implementation of relevant policy/support systems. As Zandstra (1987) has emphasized, non-threatening ways have to be sought to access policymakers. Oasa and Swanson (1986) have, in fact, pessimistically concluded that farming systems work will fail because "it ignores microeconomic and social structures that limit bottom-up development efforts." Although I agree that farming systems work was correctly conceived as a logical way of looking at the agricultural development process rather than as a development strategy per se, I prefer to be more optimistic in arguing that the farming systems approach potentially can help policymakers design and develop strategies that can channel technologies to the more disadvantaged farmers.

In addition to the issue of soft versus hard data, another matter of contention is that farming systems teams work in limited areas with limited numbers of farmers. On these two counts, attempts to build such data into representative national-level information are justifiably treated with scorn by policymakers. However, in recent years in Africa, dissatisfaction has been expressed with the work of national statistical agencies; a minority view is that greater emphasis should be placed on using simple techniques, nonrandom samples and qualitative reporting systems (Eele, 1987). If such a view were accepted generally, then data collected by farming systems teams could play a more prominent role.

It is interesting to note that several papers given at this symposium consider the necessity of relating data from farming systems projects to national surveys, resource inventories, etc. (for example, see Bertelsen et al., 1987; Brown et al., 1987; Schultink, 1987). At the very minimum, the advent of microcomputers permits data collected on farming systems projects to be properly documented and made easily accessible to other users. Used carefully, such data can be of great value. Unfortunately, it would appear that most farming systems teams do not have the time or analytical capacity to provide information in a manner that policymakers find acceptable and useful. Consequently, to provide policymakers with appropriate information, it may be necessary to have a particular person, usually an agricultural economist, undertake this task on behalf of the various farming systems teams and, in so doing, rely heavily on inputs from them. This in fact is currently being proposed in Botswana.

CONCLUSIONS

Adequate communication and information systems are a necessary but not sufficient condition for the development, dissemination and implementation of relevant improved technology and support systems (Bemis, 1985). Such systems provide an integrative function in establishing, developing and maintaining the essential linkages outlined in Fig. 2.

Although Bemis (1984) has criticized his own discipline in concentrating on the organizational and mechanical components of communication

technology, the fact is that farming systems teams, in general, have not recognized the role of such a discipline in improving their ability to communicate. Let us hope that in the mid-1980s we have learned our own limitations! Most donor projects have funds for short-term consultants, short-term and in-service training, etc., that can be used for improving such skills.

I also hope that there is a growing appreciation of the value of information systems. Different levels of information are required for different groups of actors in the agricultural development process. Microcomputers, with their database-management, spread-sheet, statistical and word-processing software packages, improve the efficiency of data management and processing as well as increase their value in easing access to other users, providing an easy means for tailoring information to different audiences. Skills need to be developed in handling such microcomputer-based systems and in writing for different audiences.

An increasing number of studies and surveys have been undertaken in recent years looking at the role played by communication and information systems in farming systems work (Trail, 1986; Colle and Scherer, 1987; Lev, 1986). There is obviously room for improvement. At the same time, the whole approach is conceptually appealing to communication and information specialists who perceive it "as a 'unique interface' between information generators and users" (Lionberger, 1986). We need the help of such specialists if there is to be any realistic hope of farming systems work being accepted within national programs in the long run. This is why implicit in so much of the discussion in the paper has been the notion that improved communication and information systems can further the "institutionalization" of farming systems work within national programs.

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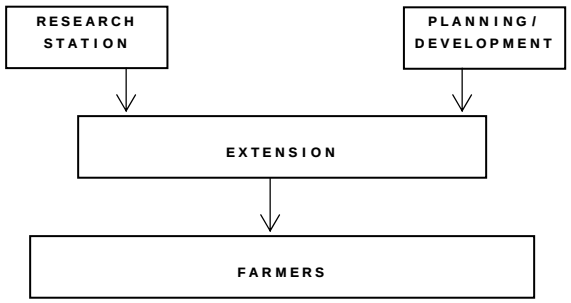

Fig. 1. The "traditional" flow of information and communication in the agricultural development process.

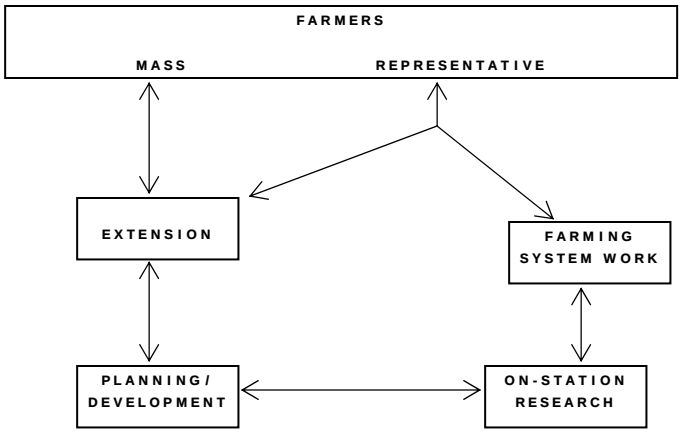

Fig. 2. The "ideal" flow.

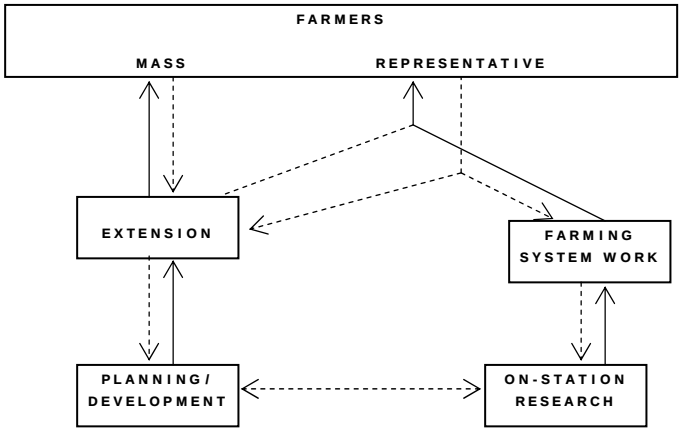

Fig. 3. The "usual" flow.

Note: Based on Lionberger (1986) and Bemis (1985) models.

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CHARACTERIZING FSR/E COMMUNICATIONS IN BANGLADESH

James H. Bemis, Jr., Peter Thorpe and Rezaul Kabir[1]

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INTRODUCTION

This paper describes the methodological approach, analytical framework and diagnostic tools that were designed and used to study communications processes at the Bangladesh Agricultural Research Institute (BARI). Focusing on farming systems research and extension (FSR/E) communications, the diagnostic tools were developed within the BARI Training and Communications Division (T&C) from March to June 1987. Primary objectives were to inventory and evaluate BARI's institutional communications capabilities and to identify and characterize BARI staff communications roles and skills. Communications training needs also were assessed, and adaptive communications training modules were designed and used in the BARI orientation and career-development course. Broad objectives were two-fold: to develop a conceptual framework for analyzing FSR/E communications, along with a cross-disciplinary working vocabulary to describe communications functions, roles and interactions; and to develop a communication strategy for networking BARI and other Bangladesh agricultural institutions. This initial methodological development anticipates further analysis and adaptation of the instruments used, as well as comparisons of findings at BARI and at related extension and academic institutions in Bangladesh.

RATIONALE AND ANALYTICAL FRAMEWORK

Systematic and effective use of communications resources in agricultural development is of crucial importance in Bangladesh, where a rapidly increasing population of nearly 120 million people occupies an area of only 54,501 square miles — about the size of the state of Arkansas in the United States. Of this population, nearly 60% of the families are classified as landless, and rivers flood about 40% of the total land

[1]Senior Associate, Winrock International Institute for Agricultural Development, Petit Jean Mountain, Morrilton, AR 72110; Information Specialist, Winrock International, Bangladesh Agricultural Research Council, Farm Gate, Dhaka, Bangladesh; Communications and Training Specialist, Bangladesh Agricultural Research Institute, Joydebpur, Bangladesh.

area each year. The literacy rate for the total population is estimated at only 15% to 20%, and youth under 16 years old make up half of the population. BARI and sister institutions play central roles in developing agricultural technology for this diverse Bangladesh environment.

In examining the research/extension system of Bangladesh, which parallels the model roughly illustrated in Fig. 1 (Lionberger, 1986a), the study borrowed heavily from other models and concepts (Fig. 1 and 2) developed at previous symposium communications presentations and workshops (Abbott and Mundy, 1986; Esslinger and McCorkle; Lionberger, 1986a; Bemis, 1984, 1985). In these earlier workshops, it was argued that systematic agricultural development is strongly and positively associated with increased information-processing skills of individuals (farmers and their families, extension workers, research workers, FSR/E teams) and with similar information management capabilities of development institutions (research, extension, planning).

Such a premise suggests that maturing institution systems require the same sorts of advanced abilities to handle new information, abstract ideas and technology as do experienced scientists — with both requiring continuous updating of knowledge and skills to operate increasingly sophisticated information-processing tools and management schemes. A related institution-building notion is that FSR/E projects must contribute to sustainability of these human and institutional capabilities or else they can have no permanent positive effects.

From a communications research perspective, FSR/E methodology is especially appealing for study of these concepts because of its demonstrated applications to a mix of cultures and knowledge bases (Zandstra, 1987). In iterative steps, the FSR/E approach combines and links the technologies of farmers, researchers and extension scientists. Such linkages demand a broad range of knowledge, communications, skills, information-processing tools and management procedures. And the FSR/E interactions span a full communication continuum of source/receivers, media and learning environments — from individual farm-family visits to institutional and international networking. Yet, few studies have examined the FSR/E approach from a communications perspective, and projects are just beginning to identify, characterize, index and compare these communications proficiencies and interactions. Similarly, few studies have documented the related communications facilities, equipment, policies and procedures.

Thus, in FSR/E design and implementation, communications technology is seldom treated as "transferable" agricultural technology, per se. In most developing countries, FSR/E project designers seem to have assumed that the necessary human and institutional communications skills and processes are assimilated or developed through previous formal education or on-the-job experiences.

Dr. Lionberger (1986b) cautions against such assumptions, and his model of the world systems for agricultural research and extension (partially depicted in Fig. 1) calls special attention to the powerful analytical and information-processing skills and roles that are learned and(or)

internalized in the knowledge development and delivery system. He also stresses the influences of interactive feedback and nonformal communications, as well as the roles of governance mechanisms and of social and institutional norms and values. Dr. Lionberger (personal communications, 1987) notes that these functions are especially difficult to describe and depict in static graphic representations. Conventional descriptive terms for such functions cover a broad range, for example, farm-family feedback, field demonstrations, intrateam activities, intrainstitutional training, professional development and formal educational efforts.

Descriptive models usually symbolize these relay functions with "arrows," as in Fig. 1, but only rarely have FSR/E projects attempted to define the transfer technology in operational terms. Although interdisciplinary FSR/E teams often cite the crucial role of these interactions, systematic analysis has been limited by the lack of methodology to measuring the communications flow in terms of rate, volume, valence, media and interactive patterns, and(or) in terms of the required human skills and institutional roles.

Recent FSR/E symposium communications workshops have tightened the FSR/E focus for closer study of the technology of transfer, including discussion structured around the working model shown in Fig. 2 (Bemis, 1986). This model can be superimposed on similar much-simplified models used by other FSR/E disciplines to describe the steps in the FSR/E approach (Shaner et al., 1982). For communications analysis, the fifth step of the model has been added to emphasize the cyclic pattern of the FSR/E communications processes. The iterative, interactive steps in Fig. 2 now include five steps:

- characterization (and recharacterization) of the communications subsystems, including information management and processing resources, products, training and related operational processes and interactions among them

- analysis to identify constraints and practical options for their resolution to streamline technology of transfer

- design and evaluation of innovations or adaptations of the existing technology and system structure, profiles useful here as benchmarks and to monitor change

- implementation of technology that is technically, economically and socially feasible

- continued evaluation, updating and analysis of information flow, database development and networking, and feed forward

Generally, these functions (detailed below) are the most innovative — and least well understood and documented. Step 5 is implicit in most earlier FSR/E models, but spelling out these functions helps reshape the research and extension vectors in Fig. 2 to reflect the iterative feedback loop from farmer to researcher. This step encompasses the traditional extension specialist translation and relay roles for which

trained personnel usually are unavailable in developing agricultural systems. Step 5 also highlights the need for systematic understanding of the farmers' perceptions and reactions over time — with documentation, analysis and longer-term storage and retrieval for immediate access by users at all systems levels and to shape the questions fed back into the research hopper.

Figure 3 further details communication functions and subfunctions that energize the model as adapted for the Bangladesh study. In the 1981 diagnostic work, the complementary models provided a common framework and basic vocabulary for cross-disciplinary discussion and analysis of related FSR/E concepts.

SCOPE AND OBJECTIVES

In broad communications context, the study's primary aim was to identify, define and operationalize the ubiquitous arrows shown or implied in Fig. 1, 2 and 3. Exploratory diagnostic tools and procedures were designed to profile the related communications roles of the T&C division, related BARI staff and research and extension components. Collaboratively, a working vocabulary was developed to characterize communications components and processes. In later steps, questionnaires were designed for use within a training environment and as part of a continuing systematic analysis.

Figure 3 depicts the concepts used to chart the initial exploratory work and to help operationalize the general functions and subfunctions of the technology of transfer. In characterizing these subfunctions, the basic units of analysis were skills and attitudes, roles and procedures, facilities and equipment and organization and policy within BARI and related institutions.

Although selected local and regional Bangladesh research, academic and extension staff and facilities were appraised in initial exploratory work, the study later focused more closely on the English-language message and media processing and management subfunctions (Fig. 3). The applied-research segment of the continuum (Fig. 1) was emphasized so that over 90 young research scientists gathered for a previously scheduled career-development training could participate in the study. This emphasis was also an accommodation for the expatriates' limited knowledge of the Bengali language. The research scientists represented most of the disciplines and organizational components of BARI and came from locations throughout Bangladesh. Thus, although the initial rapid appraisal ranged over several institutions and geographical areas, the questionnaires and more detailed diagnostic work dealt specifically with the BARI trainees and T&C staff.

METHODOLOGY

The study methodology was designed as part of, and adapted within the learning environment of, the career-development courses. Data were

gathered, and diagnostic and assessment instruments were applied and demonstrated as a learning component of the in-service training.

Dr. Lionberger's model (Fig. 1) provided a conceptual checklist for the initial diagnostic work in the larger academic/research/extension system to ensure that key relay points were taken into account. No assumptions were made about the availability of effectiveness of modern communications technology. Nor were there assumptions about the user's ability to put the technology to work (just as the FSR/E approach makes no assumptions about the goodness-of-fit of improved varieties or about the farmers' skills in using them).

The diagnostic process was user driven, as in field-level FSR/E work. users were interviewed and FSR/E sites visited at selected locations in the BARI system to identify and describe the subfunctions and interactions depicted in Fig. 2 and 3. While often representing commonplace communications events, these concepts proved difficult to specify, describe and quantify for empirical study.

Initial interviews were with the T&C staff in a rapid appraisal of current T&C operations. Then the Mymensingh region was selected for use as case study, following brief interviews and observations at several sites at Joydebpur and visits to the Bangladesh Rice Research Institute (BRRI), the Central Extension Research and Development Institute (CERDI) and the Agricultural Extension Offices in Dhaka. The path of BARI technology development and transfer was traced from BARI headquarters through the research station system at Jamalpur, focusing on related FSR/E, on-farm and multilocation testing that would allow a closer look at extension/farm-family user interactions.

The richest insights into BARI's communications functions, however, were gathered from the novice research workers in the T&C orientation course. Their average age was 27 years and average work experience, 3 years. The study designers participated as resource staff in specifically focused communications training sessions that permitted first-hand interaction and assessment of the trainees over a 6-week period.

Based on this experience and initial interviews with T&C staff, questionnaires and rough diagnostic instruments were specifically designed to index and assess the subfunctions depicted in Fig. 3. Both current status and perceived needs were addressed. (See selected questions, Appendix A.)

Operationally, the trainee responses were expected to define and index the following:

- occupational roles, organizational procedures, policies and basic education and subject-matter

- media used and how often, where information is obtained, and systems for processing, storing and retrieving

- media production and management skills

- facilities and equipment used

- types and levels of mixed-media interaction and learning environments

Table 1 lists the measurement descriptors shown in Fig. 3, with examples of how the concepts were operationalized in the sample questions (Appendix A).

The questionnaires were structured to complement the specially designed 2- to 4-hour courses that included agricultural communications concepts and strategies in development; message treatment for print media; scientific report writing, writing popular articles; library use; design of audiovisual presentations; general photographic principles; and training-needs assessment.

Because training sessions were conducted in two groups (group A and B) at separate times and locations, questionnaires were administered to the two groups separately. In the communications training, groups A and B were divided into 4 teams each, 10 to 12 trainees on each team. The questionnaires were built around the subject matter and exercises within each of the learning sessions and thus became an integral part of the course. For example, the initial sessions covered general communications theories, models and processes, providing an explanatory conceptual base before the questionnaire was administered. The questionnaires and procedures were designed and adapted as the course progressed, with trainee and staff responses and suggestions prompting additional questions that were included in later sessions. Sets of questions were prepared and administered weekly.

Each of the eight teams was treated as a unit, with team homework assignments for applications of the training concepts and vocabulary used in the questionnaires. T&C staff helped to administer and monitor the questionnaires, which were not recovered until the end of the course. The teams competed for best-performance awards, including completion of the questionnaires.

Further analysis is under way to tie findings to the conceptual framework and to construct trainee profiles. The sample questions listed in the appendix are grouped within the matrix of functions and subfunctions diagrammed in Fig. 3.

Thus, in the hierarchial framework for analysis of the trainees' responses, the higher-level study context is the applied-research subsystem at BARI (Fig. 1). The functions and subfunctions (Fig. 3) are conceptualized as the major processes within lower-level subsystems. The basic units of analysis are labeled as descriptors and are the processing tools (technology of transfer) operationally defined by the questions. When combined as an index or yardstick, these descriptors can profile the relative communications capabilities of individual trainees as well as other components of the BARI subsystem (disciplinary departments, divisions, administrative levels). In future analyses, comparisons could be made among other subsystems in Bangladesh (FSR/E and other research units, academic, extension, T&V).

At present the questionnaires are being coded for cross-tabulation and analysis by microcomputer, using Lotus 1-2-3, dBase III and Reflex software.

The young BARI trainees work primarily at the applied-research level of the continuum shown in Fig. 1, with heaviest workloads depicted by the research vector shown in Fig. 2. However, the diagnostic tools developed here also are intended for further assessment and comparisons of BARI's research, extension and FSR/E components. The questionnaires and procedures are considered as only first approximations of applied communications technology of transfer. As such, these tools are, per se, agricultural technology that may be adapted and used elsewhere in the FSR/E interdisciplinary team approach.

In this study, because the expatriates lacked Bengali language skills, application of the methodology was restricted primarily to the BARI trainees and T&C staff, all of whom were college graduates with only a limited, working knowledge of English. Despite the bilingual assistance of local staff, this lack of local language capability was especially frustrating in field-level assessments of research/extension/farmer linkages. However, language limitations also were evident in administration of the diagnostic questionnaires when trainees failed to understand the English-language questionnaires and found it difficult to write precise responses. Decoding the handwritten answers has been especially difficult. T&C staff helped in the design and application process, however, and are continuing translation, with appropriate additions and adaptations. (Pragmatically, for both the trainees and the instructors, the language difficulties served as a valuable demonstration of the need for cross-cultural, multi-lingual skills in the technology of transfer, at least within the international networks built around English-language usage).

With these continuing local-language adaptations, the multiple sources and receivers implied in Fig. 1, 2 and 3 can be characterized and ideally would proceed through each of the subfunctions and steps of the models over several sessions. This would involve study of a series of simultaneous information generators/users — the FSR/E team, the academic/research/extension workers, the farm family and the networking participants. Similarly, other system components and processes identified in the models could be taken to account. In effect, the interactive arrows of communications can be further charted and linked conceptually to Fig. 1, 2 and 3. More precise identification can be made of functions and subfunctions that influence direction of flow, valences and sender/seeker dimensions at each system level (as in the following discussion).

IMPLICATIONS FOR EXTENSION AND OTHER INSTITUTIONS

Because of extension's crucial role in relaying information between BARI and the ultimate farm-family user, clarification of the subfunctions represented in Fig. 3 can be particularly useful in second-phase adaptation and translation and use by extension and training-and-visit system (T&V) staff. Collaborative analysis of the interactions depicted

in the models can provide a working guide to more precisely describe and evaluate academic/research/extension communications roles.

For example, in previous symposium workshop discussions of Fig. 1 and 2, participants have pointed out that the iterative phases of FSR/E approach demand both a research (develop/document) and extension (deliver/relay) perspective. Extension users of the model were quick to note that Fig. 2 assumes the viewpoint of a research-based FSR/E team that would emphasize technology development. For use within an extension-based project, they suggested that the model should be graphically depicted in a mirror-image or reversed process. They argued that the relative FSR/E workloads of extension — or of research — would depend upon when and where the process was initiated, and by whom. Similarly, responsibilities would shift for initiating interactive feedback and feed-forward of information.

In the interactive relay of information nearer the middle of both Fig. 1 and 2 (disregarding institutional emphasis), the FSR/E team approach has demonstrated capabilities in strengthening the analysis, interpretation, feedback and delivery functions. Many of these functions have traditionally been performed by extension specialists in the research and extension delivery systems of more industrialized countries. Too often, however, the importance of these specialist roles and those of commercial and industrial counterparts is not fully provided for by development planners in Third World countries. Often there simply are no appropriately trained staffs to serve as the crucial bridge between research and extension and to smooth the central transitional steps shown in Fig. 2. In Bangladesh and other developing countries, analysis, interpretation, feedback and delivery often are performed at all levels (academic, research, extension) by staff trained in the biological sciences. They usually work with makeshift equipment — within a minimal framework of communications policy.

From an institutional perspective, the responsibility for carrying out these functions is increasingly difficult to delineate, even within established systems. Although administrators may appreciate the cross-disciplinary and intersystem strengths of the FSR/E approach, the FSR/E team activities tend to blur many of the academic/research/ extension roles shown in Fig. 1 and 2 — especially as information processes speed up and are handled nearly simultaneously in the various FSR/E phases. FSR/E methodology compresses and accelerates the relay roles — the interactive arrows in the figures — while stretching the team members' information-processing and message-treatment skills. Moreover, today's electronic media further shrink the time and distance between the system components while institutional administrators and planners attempt to manage a constantly shifting and expanding range of target audiences, media and development goals. As a result, FSR/E data storage, documentation, retrieval and packaging require continual adaptation and accommodation to traditional delivery systems (and vice-versa).

Assessment of related Bangladesh agricultural institutions (academic, research, extension, T&V, upizalas) using Bengali-adapted diagnostic tools can provide the basic management information that BARI requires to develop a longer-term communication strategy. Such a strategy would

include development of staff skills, improved facilities and equipment and systematic drafting of policy and working procedures.

Over the longer term, this systematic approach optimizes the bottom-up contributions of the indigenous knowledge base — that of the farm families and the current technology-transfer systems. Simultaneously, it provides the working tools to help fit institutional and staff capabilities to meet the demands of specific Bangladesh farming systems. Full implementation plans can be developed through the interdisciplinary systems approach, taking into account the total systems needs but emphasizing those of the rural families. Within the larger national and international systems (Fig. 1), however, planners in Bangladesh and elsewhere in the Third World should anticipate complex equity issues, with continuing need to protect "techno-peasants" — at all system levels in an increasingly information-rich society.

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APPENDIX
SAMPLE QUESTIONS AND MATRIX FOR ANALYSIS

Sample questions are listed here in abbreviated form taken from the original battery of seven questionnaires administered to the BARI trainees. They are grouped under the matrix functions and subfunctions identified in Fig. 3.

In the hierarchial framework for analysis of the trainees responses, the higher level study context is the applied-research subsystem at BARI (Fig. 1). The functions and subfunctions (Fig. 3) are conceptualized as the major processes within lower level subsystems. The basic units of analysis are labeled as descriptors and are the processing tools (technology of transfer) operationally defined by the questions. When combined as an index or yardstick, these descriptors profile the relative communications capabilities of individual trainees as well as other units of the BARI subsystem (disciplinary departments, divisions, administrative levels). In future analyses, comparisons could be made among other subsystems in Bangladesh (FSR/E and other research units, academic, extension, T&V).

Additional working tools are being generated from the questionnaire responses. The questions are designed to explore and develop operational definitions and a working vocabulary for analysis and discussion of the descriptors that characterize the subfunctions shown in Fig. 3 — the skills, roles, procedures, facilities, equipment, organization, policy and attitudes (norms/values).

FUNCTION 1: GENERATION

Subfunction 1.1 Data Gathering (Research Methodology)

Sample questions:

1.1.1 In survey work and research design and data collection, do you require services for:

1.1.1.1 Survey/questionnaire design?
1.1.1.2 Data coding and tabulation?
1.1.1.3 Data analysis/statistical treatment?

(Format for each of these questions was as shown below.)

Use rate: Never ____ Occasional ____ Monthly _____
Weekly ____ Daily ____

Please describe how you use: _____

How improve services? _____

Subfunction 1.2 Storage and Retrieval

1.2.1 Does your office have central files or storage for technical/research information?

User rate: Never ____ Occasional ____ Monthly _____
Weekly ____ Daily ____

Where/how use? (Please describe procedure for your filing or use of technical reports/research results for 1986-1987).

_____

(A separate questionnaire dealt with types of media and systems used for managing, storing and retrieving technical information. Media included books, journals, bulletins, newsletters, technical reports, training and shortcourse material, graphics/maps/charts, slides, transparencies, policy/procedures and letters/memos. Systems were coded as 1) standardized systematic indexing and classification systems, 2) personal or works-for-me and 3) loose, random collection. The general format is shown in the sample below:

Media	System used	Comments/suggestions
Books	2	
Journals	1	

Subfunction 1.3 Planning and Needs Assessment

(This topic was included at last training course. No questionnaires were prepared. Novice trainees have had minimal experience.)

FUNCTION 2: DELIVERY/EXCHANGE

Subfunction 2.1 Message/Media Management and Processing

(The study emphasizes subfunction 2.1, which is further divided into subprocesses, with descriptors also having additional subclassifications build around code, content and treatment capabilities.)

Subprocess 2.1.1 Feed Forward (Interactive relay to intended end-user)

Sample questions:

(Standard response format: complete ____ incomplete ___)

Bangla ____ English ____

Where and how used: _____

Use rate: Never ___ Occasional _____ Monthly _____
Weekly ____ Daily _____

2.1.1.1 Within the last 3 years (1984-1987), how many of the following media have you prepared, published and presented.

2.1.1.1.1 Author or co-author of journal articles for BARI journal?

2.1.1.1.2 Presentation of seminar at BARI?

2.1.1.1.3 Presentation of radio broadcast?

2.1.1.2 In your daily work over the past 12 months, you may have used some of the following communications services and facilities. Please describe:

2.1.1.2.1 Dictionary

2.1.1.2.2 Secretarial/correspondence guide

2.1.1.2.3 Style/technical writing guide

Subprocess 2.1.2 Feedback (Interactive relay from intended user).

A separate, partially structured questionnaire was used to capture several dimensions of user feedback and feed-forward, as well as source/user interaction. This questionnaire matrix was called Types and Levels of Mixed-media Interaction. Trainees were asked to describe their work with

2.1.2.1 media (flip charts, lecture, video, etc.)

2.1.2.2 location/environment for use (farmers fields, station plot, farmer home, training facility, etc.)

2.1.2.3 type of interaction (demonstration trial, seminar, office visit, T&V monthly meeting)

2.1.2.4 audience makeup percentage (research, extension, farmer, etc.)

2.1.2.5 language used (Bengali, English, other)

2.1.2.6 general (geographical location, gender, size group)

FUNCTION 3: USE

Subfunction 3.1 Access

This subfunction merited stronger emphasis. As the training course progressed, new insights were gained and questions added. However, the

access dimensions of the source, relay and receiver roles should be stressed in future local-language diagnostic work.

3.1 In your research work, what libraries and information services do you use?

(Standard response format: Use rate: Never _____Occasional ___ Monthly ____ Weekly _____ Daily _____

Please describe how you use: _____
How improve service? _____

3.1.1 BARI library
3.1.2 Other library/information services

3.2 If an extension agent (farmer, researcher) requests information or recommendations from you or your working unit, what policy or procedures are used?

Subfunction 3.2 Networking

The general notion of information sharing was used to classify the networking questions. Conceptually, there was a great deal of difficulty in sorting out the access, networking and integration questions. The questions here deal primarily with professional-level networking.

(Standard response format: Use rate: Never _____ Occasional ___ Monthly ____ Weekly _____ Daily _____

Please describe how you use: _____
How improve service? _____

3.2.1 In the last year:

3.2.1.1 How many professional society (symposia, conferences, training sessions) have you attended?

Subfunction 3.3 Integration

This question explores the adaptive and additive dimensions of information use over time — probably the least-discussed concepts in traditional adoption and diffusion studies. (Paradoxically, the whole national and international research/delivery process is now designing services capable of near-instantaneous methods to validate, update, improve and(or) replace today's technology with tomorrow's. Responsibilities for these functions in FSR/E work are particularly difficult to sort out.)

3.3.1 Does your working unit maintain a list of approved recommendations or data file for recommendation?

3.3.2 When formal recommendations are approved from your research or from that of others in your work unit, what procedures are used?

(Standard response format: Use rate: Never _____ Occasional ____ Monthly _____ Weekly ____ Daily ____

Please describe how you use: _____
How improve service?_____

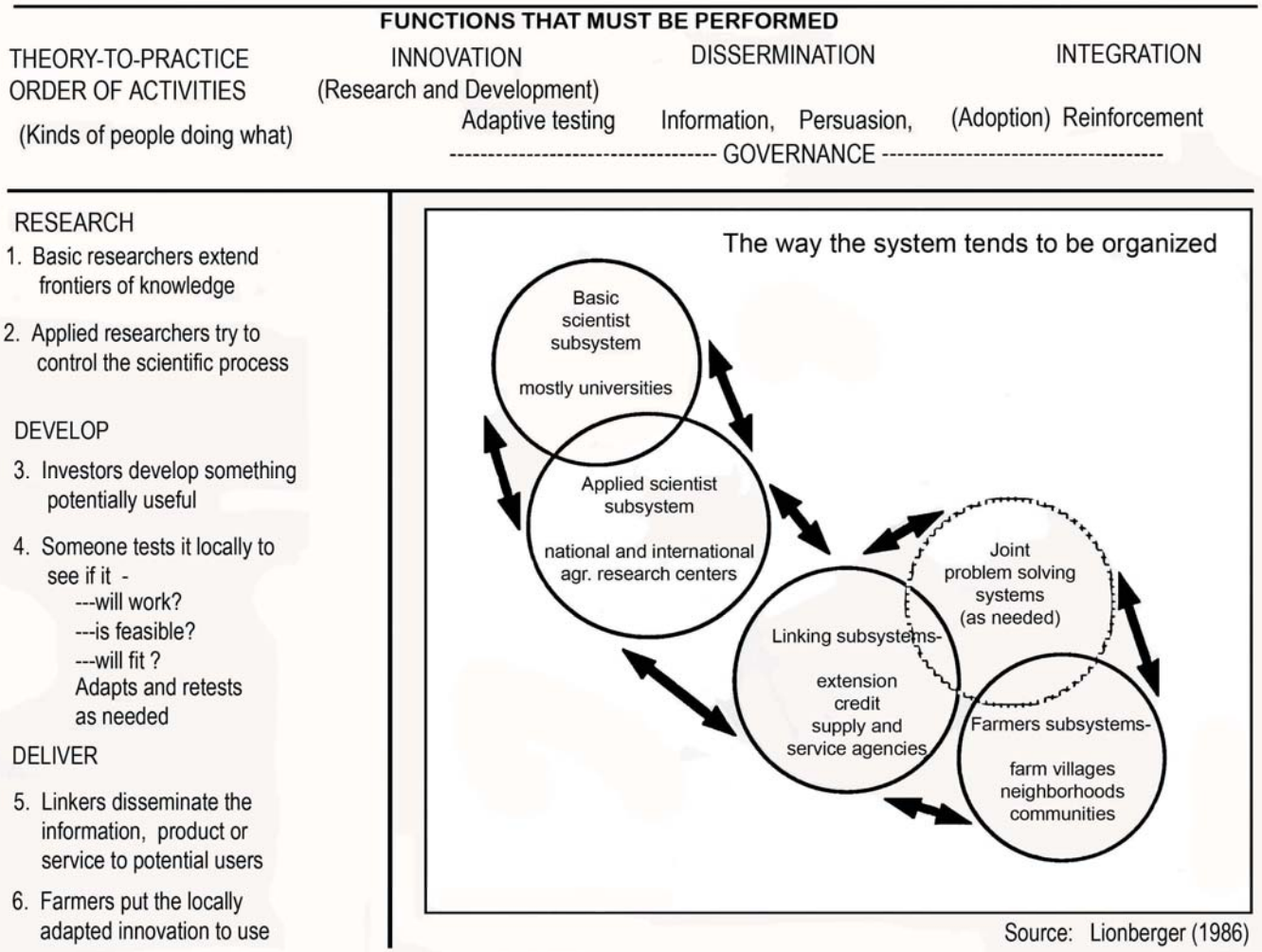

Fig. 1. The farm information supply system.

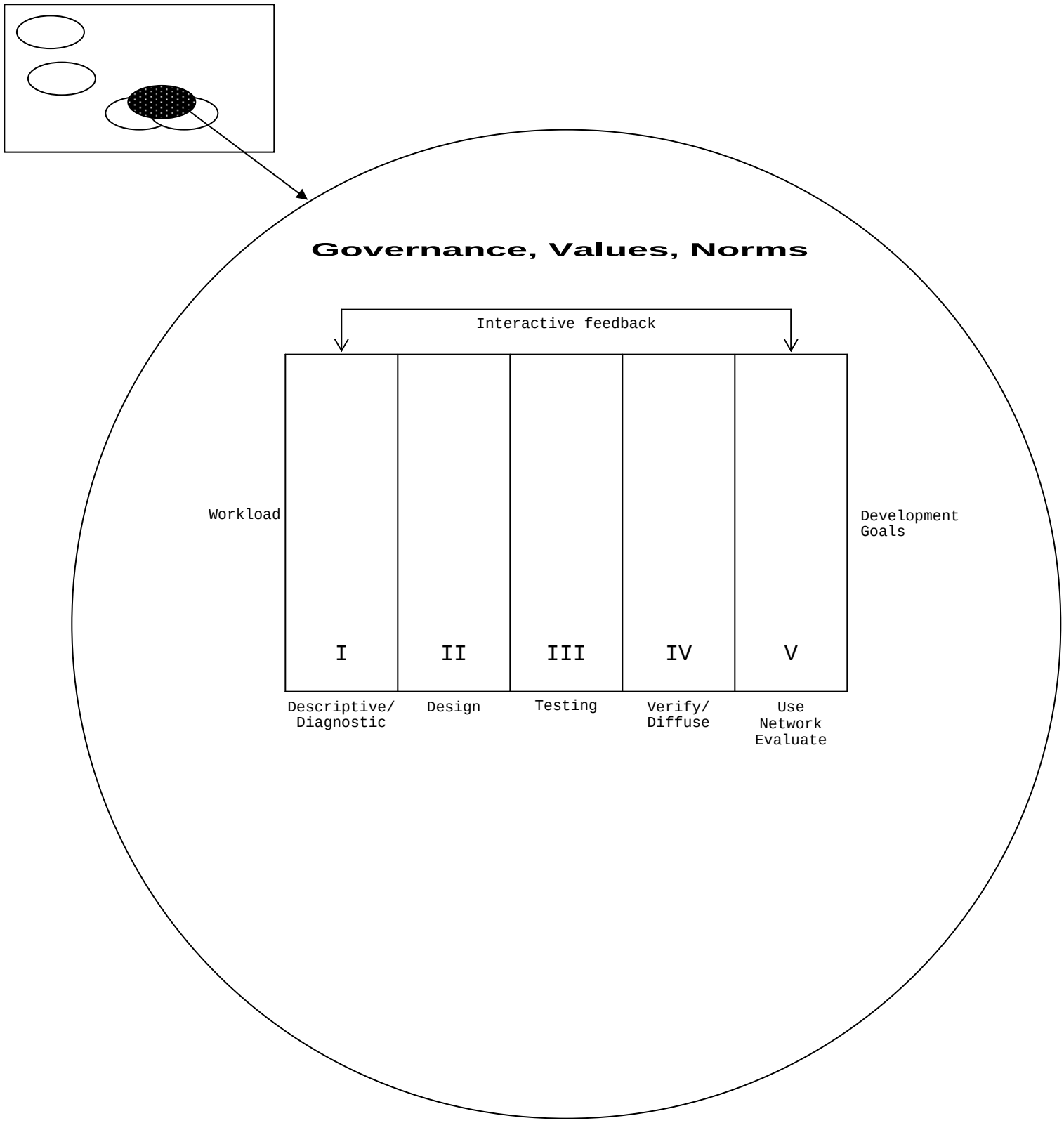

Fig. 2. Steps in a typical FSR/E approach.

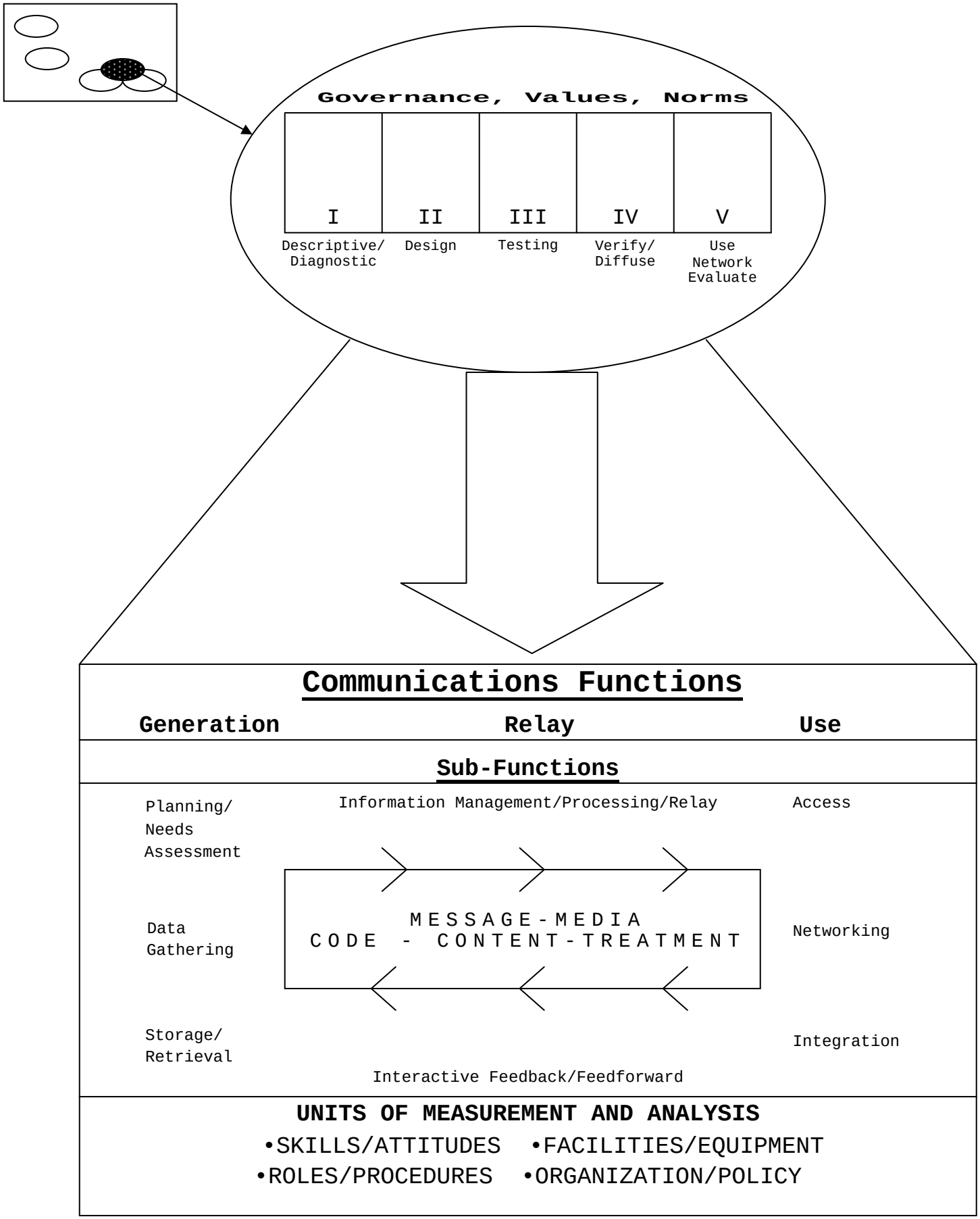

Fig. 3. Technology of transfer functions, subfunctions and units of analysis to characterize FSR/E communications.

Table 1. Units of measurement and analysis as operationalized in the questionnaire.

Measurement Descriptors	Operational level for questionnaire
Skills	Use of language, statistics, computer
Attitudes	T&C credibility, capability
Roles	Author, processor, secretary, researcher
Procedures	Submission of journal MS; use of library style guides, field days, seminars
Facilities	Office space, phone, electrical equipment/services
Equipment	Dictionary, typewriter, camera
Organization	BARI administration structure, divisions and related control patterns
Policy	Publish/perish reward system; use of English versus Bengali

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THE VALUE OF INFORMATION FROM A NATIONAL AGRICULTURAL SURVEY: INFERENCES FROM EXTENSION OF FSR/E RECOMMENDED PRACTICES IN HAITI

Michael K. Bertelsen, R. Quentin Grafton, and Richard Swanson[1]

INTRODUCTION

Economic evaluations of information systems such as the Haitian National Agricultural Survey are important though largely neglected activities. Throughout much of the world, the development of improved information systems is generally given a low priority. Government and donor agency policy-makers and analysts need to be aware of the potential value of improved information, not only to evaluate choices among alternative information systems, but also to understand the trade-offs in allocating limited resources to these systems and among other programs that depend upon the information developed by these systems.

FSR/E projects examine all relevant interrelationships among the natural and human environments. As a result, the number of households and locales that can be served by these projects is limited. Further, the considerable cost of FSR/E may outweigh the benefits of the recommended management and technology improvements if broad extension efforts of the appropriate recommendation domains is insufficient. It follows that FSR/E projects need extensive national and regional agricultural information to evaluate the expected benefits of extending, to regionalize recommendations domains and to focus the extension effect.

This paper examines the value of information derived from a recurrent national agricultural survey in Haiti through a proposed extension information system to extend FSR/E project results. The analysis compares the crop and area estimates provided by the new and old information systems. The resulting projection of net benefits for the proposed extension program, based on results from the FSR/E project in one department of Haiti, are discussed. The difference between the value of the extension program investment decision likely to be taken "with versus without" the new information is presented as a partial estimate of the value of the survey information.

PROBLEM STATEMENT

Information has value if it can lead to improved decision-making. The difficulty in assessing the value of information is that its worth will vary according to the user. Since obtaining information is not a costless activity, the valuation of information provides a means to assess the net benefits of gathering it. In the Third World, where there is a dearth of information, such evaluations are especially important. Hence, by evaluating the benefits of gathering information

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[1]National survey economist (Winrock International); agricultural economist (Winrock International); and economic anthropologist and team leader (University of Arkansas) for the Haitian Agricultural Development Support Project II.

and of other development projects, a more efficient allocation of domestic and donor funds can result.

In an assessment of Haiti's National Agricultural Survey, the value of its crop area and yield estimates is assumed to be equal to the value of the decision concerning future funding for extending FSR/E-recommended practices provided that this new information modifies existing or probable decisions using old information. Consequently, the problem requires evaluation of the potential net benefits of extending the FSR/E-recommended practices under crop area and yield conditions described "with versus without" the new information.

To accomplish this, the results of the FSR/E project in the Southern Department of Haiti were combined with the estimates of crop yields and areas from the recurrent national agricultural survey, projecting estimates of net benefits of extending improved farming systems practices. The net benefits of this analysis were then compared to an identical evaluation using presurvey estimates of crop yields and areas for the same recommendation domains. As a result, the value of information derived from the national survey and the value of extending FSR/E project results were shown concurrently.

BACKGROUND

Since February 1984, the Agricultural Development Support II Project (ADS-II) has been engaged in FSR/E in the Jacmel and Les Cayes regions of Haiti, located, respectively, in the Southeastern and Southern Departments of the country. The FSR/E team has worked with virtually all important food crops cultivated in its zones of intervention. However, success of on-farm research varies among some crops. Although considerable progress has been made towards identifying improved varieties of rain fed rice, cowpeas, sweet potatoes and bitter manioc, the most successful practices introduced and tested by the project have been those developed for maize, sorghum, irrigated rice and black, beans. The recommended practices include higher-yielding varieties for each of these four crops and the use of fertilizer for the production of maize and rice. A summary of yields under traditional practices for these crops and projected average increases available from adoption of ADS-II practices recommended are presented in Table 1.

The accepted yield percentage increases stemming from the adoption of recommended practices were calculated from ADS-II FSR/E results of farmer-managed pre-extension trials. These trials took place in four subzones of intervention involving some 600 households between 1984 and 1986 (Project d'Apui au Developpement Agricole, 1987). Because a majority of the trials in the Southern Department involved monoculture crops, the projected percentage yield increases are applicable only to monoculture cropping systems, which are found primarily on the intensively cultivated plains and hillsides of the Southern Department.

The ADS-II National Agricultural Survey was initiated in April 1985. Beginning as a pilot survey in the Southern Department during the second agricultural season of 1985, the survey has gradually expanded its

seasonal geographical coverage to the entire country. The survey uses an open-segment, area-frame methodology (Bertelsen et al., 1986) and has generated the first comprehensive information derived from a probability sample ever presented on basic agricultural activities in Haiti.

The ADS-II survey estimates presented in Table 1 are the average, seasonal yields, based on farmer recall, from the intensive plain or intensive mountain stratum in the Southern Department for 1985 and 1986 (Bertelsen et al, 1987). The intensive states are defined as those areas having at least 40% of total land area in field-crop production as determined by interpretations of aerial photography of the region. Yields from these strata are analyzed because households in these strata bear the closest resemblance to the farming systems types present in the zones where the FSR/E research trials were conducted and the recommended practices were developed (FSR/E traditional yield trial estimates were generally higher, especially in the case of rice, than those analyses because they cannot be considered representative of average yields for the strata in question.)

The Haitian Ministry of Agriculture (MARNDR) estimates presented in the table were derived from informal surveys of ministry officials and, prior to the ADS-II survey, represented the best available information on crop areas and yields (Service de Statistiques Agricoles, 1980). Within the context of this analysis, these estimates represent the results of the previous information system. The MARNDR estimates have no probability basis and few statistical pretensions and are not available at any subdepartmental level. Because these estimates are only on a departmental basis, they represent an average of yields for crops grown in monoculture and also in association. Since the yields for crops grown in association are generally lower than those for monoculture crops, a departmental average of the two would likely give lower yield estimates than one would expect for the relevant recommendation domains in the analysis. The ADS-II estimates suffer the same problem since they too are yield estimates that are averages of crops grown in monoculture and in association. However, since the ADS-II estimates are on a subdepartmental level representing yields from the intensive plain and mountain stratas where monoculture practices are much more common than in the department as a whole, the downward bias is likely to be less than for the MARNDR data.

CONCEPTUAL MODEL

In economic theory, the value of information is associated with the "expected utility gain" that can be obtained through the use of the information in question. For example, Perrin (1976) defines the value of information as "...the increment in expected payoff (in terms of utility) that can be realized by utilizing the information in making the decision." Although "expected utility gain" is the accepted theoretical criterion for measuring the value of information, economists universally opt for an admittedly inferior, though practical, approximation for applied problems. The expected monetary payoff is substituted for the abstract and unmeasureable utility concept.

In applied economic analysis, the expected monetary payoff criterion is many times manifested by attempts to identify what consumers of some commodity would be "willing to pay" for different quantities of the commodity. Implicit in the use of willingness to pay is the assumption that consumers can evaluate in monetary terms the expected utility payoff received from the commodity and could express this payoff in terms of the amount they would be willing to pay for it. In benefit/cost analyses of public policies or investment decisions, willingness to pay is often assumed to equal the sum of the monetary benefits that accrue to affected parties. In analyzing these types of problems, economists estimate the net monetary benefits that have or would accrue "with versus without" the policy or investment.

The model used to derive the estimated net benefits from adoption of the FSR/E-recommended practices with extension, calculated with and without the new information, is presented in expression 1.

Expression 1

$$NB = \left| \sum_{i=1}^{i} \sum_{n=1}^{n} \left[\left(\left[(Hs_{in}\, Ys_i\, P_i\, Ae_{in} - Hs_{in}\, C_i\, Ae_{in}) - (Hs_{in}\, Ys_i\, P_i\, Ac_{in}) \right] - \left[Hm_{in}\, Ym_i\, p_i\, Ae_{in} - Hm_{in}\, c_i\, Ae_{in} \right) - (Hm_{in}\, Ym_i\, p^i\, Ac_{in} - Hm_{in}\, C_i\, Ac_{in}) \right] \right) / (1 + r)^n \right] \right|$$

where:

- NB = absolute difference between the dollar value of the discounted projected net benefits of an extension program of FSR/E-recommended practices calculated from ADS-II and MARNDR estimates of crop area and yield
- Hs_{in} = estimated crop area recommendation domain, in hectares, derived from the ADS-II survey using the FSR/E-recommended practices for crop i in time period n
- Hm_{in} = estimated crop area recommendation domain, in hectares, derived from MARNDR using the FSR/E-recommended practices for crop i in time period n
- Ys_i = estimated expected increase in yield (kg/ha) derived from ADS-II national survey estimates from using FSR/E-recommended practices for crop i
- Ym_i = estimated expected increase in yield (kg/ha) derived from MARNDR estimated from using FSR/E-recommended practices for crop i
- P_i = average price (US$/kg) for crop i in 1986
- C_i = marginal cost (US$/ha) from using the FSR/E-recommended practices for crop i in 1986

Ae_{in} = proportion of the area of the defined recommendation domain using the FSR/E-recommended practices as a result of the extension program, for crop i in time period n

Ac_{in} = proportion of the area of the defined recommendation domains using the FSR/E-recommended practices without an extension program, for crop i in time period n

r = discount rate

n = time period in years.

Implicit in expression 1 is the likelihood that the greater the difference in the projected net benefits calculated from the two sources of information, the greater the chance that the ADS-II national survey information may change an existing or future decision to invest (or not invest) in the extension program of the FSR/E recommended practices, ceteris paribus. If the difference in the projected net benefits of extension between the two information sources is sufficient to change a policy decision from noninvestment to investment in an extension effort, the value of information from the ADS-II survey is equal to the sum of the discounted net benefits, calculated using the survey estimates of crop areas and yields, less the discounted cost of the extension effort.

Expression 1 may be solved in its entirety or by component parts. The first bracketed term, [(HsYsPae - HsCAe) - (HsYsPAc - HsCAc)], is the projected increase in aggregate net benefits from adoption of the FSR/E-recommended practices with an extension effort, less the projected increase in aggregate net benefits from adoption of the FSR/E-recommended practices that would occur without an extension effort, using the crop areas and yield estimates from the ADS-II survey. The second bracketed term, [(HmYmPAe - HmCAe) - (HmYmPAc - HmCAc)], is the same projected increase in aggregate net benefits, but calculated using the MARNDR estimates of crop areas and yields.

The net benefits from adoption of the recommended practices that would occur without a formal extension effort are subtracted from the net benefits that would occur with an extension effort in both bracketed terms in order to avoid an overestimation of net benefits attributed to the extension effort. A formal extension effort is seen as a method to raise the natural rate of adoption so as to ensure an earlier accrual of the projected net benefits. A formal extension program for recommended practices causes a shift in the natural adoption curve to a new and higher adoption curve. Conceptually, the gross benefits of a formal extension program are represented by the discounted value of the area between the two adoption curves. If these gross benefits exceed the cost of the extension effort, then the extension program has a positive societal value.

Due to a variety of factors, including the relative riskiness and profitability of the individual recommended practices, differing adoption rates for each crop in expression 1 would be expected. However, for simplicity we have assumed equal relative adoption rates

over all crops in each extension scenario presented below in the analysis.

For ease of interpretation, expression 1 may be rewritten as in expression 2:

Expression 2

$$NB = \left| \sum_{i=1}^{i} \sum_{n=1}^{n} [(Ae_{in} - Ac_{in}) [(Hs_{in} Ys_i P_i - Hs_{in} C_i) - (Hm_{in} Ym_i P_i - Hm_{in} C_i)]] (1 + r)^n \right|$$

This expression indicates that the difference in projected net benefits of extension from the two information sources equals the difference between the program-induced and natural rates of adoption multiplied by the difference in net benefits implied by each information source.

By differentiating expression 2 with respect to the adoption rates with and without extension, one can determine the effect upon the difference in the projected net benefits of extension implied by the two sources of information as the adoption rate rises from an extension effort. This is illustrated in expression 3:

Expression 3

$$NB / (Ae_{in} - Ac_{in}) = \sum_{i=1}^{i} \sum_{n=1}^{n} [(Hs_{1n} Ys_i P_i - Hs_{in} C_i) - (Hm_{in} Ym_i P_i - Hm_{in} C_i)] / (1 + r)^n$$

As the difference in adoption rates with and without extension increases, the difference in the projected net benefits from the two sources of information also increases.

Differentiating expression 2 with respect to the discount rate, we see that as the discount rate increases, the difference in the projected net benefits of extension from the two information sources decreases. Hence, the higher the discount rate, the smaller the difference in the net benefits of extension between the ADS-II crop area and yield estimates compared to the MARNDR information. This is illustrated in expression 4.

Expression 4

$$NB / r = \sum_{i=1}^{i} \sum_{n=1}^{n} [(Ae_{in} - Ac_{in}) [(Hs_{in} Ys_i P_i - Hs_{in} C_i) - (Hm_{in} Ym_i P_i Hm_{in} C_i)]] (1 + r)^n$$

ANALYSIS AND DISCUSSION

The data used to analyze the problem are presented in Table 2. The crop areas for the ADS-II national survey represent estimates of the areas of

the relevant recommendation domains and are equal to the total estimates of areas grown in monoculture for each crop in the Southern Department of Haiti. Although no department-level estimates for monoculture areas from the MARNDR source exist, national estimates of monoculture proportions are available (Service de Statistiques Agricoles, 1980). These proportions were assumed to be the same for the Southern Department, and the MARNDR estimates of crop area were adjusted accordingly.

Market prices used to evaluate the net benefits of the recommended practices are annual averages of price data collected weekly by the ADS-II FSR/E team from five local markets in the Southern Department throughout 1986. The marginal cost data for the recommended practices were obtained from the previously mentioned farmer-managed pre-extension trials undertaken between 1984 and 1986.

Table 2 indicates that, with the exception of the yield estimate for black beans, all ADS-II estimates are higher than corresponding MARNDR estimates. Thus, even without the benefit of using expression 1, it is apparent that the projected net benefits of an extension program would be higher using the ADS-II estimates than using the MARNDR estimates. However, as previously discussed, it is probable that the MARNDR yield estimates have a greater demand bias than do the ADS-II yield estimates. Nevertheless, it is extremely likely that bias-adjusted yield estimates would be sufficient to offset the large differences in area estimates in the net benefit calculations.

The values in Table 2 were used to solve the component parts of expression 1 under differing scenarios of projected adoption rates and discount rates. It was assumed that the maximum rate of adoption would be achieved at the end of the fifth year of a formal extension effort. Under the extension-effort scenarios, maximum adoption rates of 10%, 25% and 50% of the estimated areas for each crop were assumed. Adoption of the recommended practices without extension was assumed to be 1% of the estimated areas for each crop at the start of year 1 and to increase at a compounded rate of 10% per year. In all three extension-effort scenarios, the adoption of the practices at the start of year 1 was the same as for the natural rate of adoption without an extension effort.

The rate used to discount future costs and benefits is crucial in determining the value of the projected net benefits of an investment. Often, the market rate of interest is used since it should reflect the opportunity cost of the capital invested in a proposed project. Disadvantages of this approach include the fact that there is never one single market rate of interest and that, even if one existed, such a rate would not adequately reflect society's regard for consumption by future generations. Hence, in investment evaluation it is useful to determine the sensitivity of projected net benefits to different discount rates. The three discount rates chosen to determine the net benefits of an extension program of the FSR/E-recommended practices were 10%, 25% and 40%. The 25% discount rate is the approximate rate of interest on borrowed (bank) capital in Haiti. The 10% rate is close to the discount rate currently used by the U.S. Agency for International Development in Haiti (USAID/Haiti) for evaluating project investments. The 40% rate reflects the authors' perspectives concerning the

appropriate rate of discount to use for public investment decisions in Haiti.

The projected net benefits of a 5-year extension effort under the differing scenarios of adoption rates and discount rates is presented in Table 3.

Table 3 indicates a wide range of values for the projected net benefits of an extension program. The highest total net benefit projections are, respectively, some $29 million and $59 million for the MARNDR and ADS-II estimates calculated under the 50% adoption and 10% discount-rate assumptions. The lowest total projected net benefits stem from the 10% adoption and 40% discount-rate assumptions and are approximately $700,000 and $1.4 million, respectively, for the MARNDR and ADS-II estimates.

The net benefits from the extension program outweigh costs under all scenarios using ADS-II data except those under the 10%-adoption rate and 40%-discount-rate assumptions. Using the MARNDR data, costs exceed benefits under the 10% adoption rates for the 24% and 40% discount rates and the 25% adoption rate for the 40% discount rate. Since expression 1 is linear in adoption rates given any discount rate, the figures may be used to determine approximate breakeven adoption rates for each discount rate. Thus, under the 25%-discount-rate assumption using the MARNDR information, a $2-million investment in extension would break even if the extension effort converted approximately 12% of the crop area to the new technologies. Using the ADS-II information for the same scenario, the extension program would provide net benefits over the entire range of indicated adoption rates. Under the 40%-discount-rate scenario, the breakeven adoption rates would occur around 13% for the ADS-II information and 29% for the MARNDR information. Under the 10%-discount-rate scenario, both information sources indicate the extension program would provide net benefits over the entire range of indicated adoption rates.

The appropriate scenario to use in evaluating the potential value of the FSR/E research through investment in the extension program, and, concurrently, the value of the national survey information, remains somewhat subjective. The subjectivity stems more from likely disagreements concerning the appropriate discount rate to use than from disagreements concerning appropriate and feasible target extension-adoption rates. Probably most policy analysis would accept an adoption rate of 25% of the recommendation domains as an appropriate and feasible target for a formal extension effort in the Southern Department. A 25% adoption would represent a conservative but, at the same time, substantial contribution to welfare of Haitian farmers. The appropriate discount rate is another issue.

Given the present uncertain sociopolitical climate in Haiti, the low relative level of development, the large number of potential and cost-effective alternative investment programs this underdevelopment implies and the high informal interest rates paid by Haitian farmers, a high discount rate would be appropriate for evaluating any proposed extension project. Consequently, the authors argue for the most conservative discount-rate scenario presented above.

Given the results of the analysis in Table 3 for the 25% adoption rate and 40% discount rate, estimated values for both the potential benefits of the extension program of FSR/E-recommended practices and the national survey information can be determined directly. The total estimated value of the FSR/E-recommended practices is some $3.5 million. If a $2-million extension project is required to achieve the 24% adoption rate in the Southern Department, this would imply a benefit/cost ration of 1.77. Furthermore, since the analysis using the MARNDR information would preclude the extension project and the gain in net social benefits resulting from the 25% adoption rate, the value of the national survey information in this case is equal to the difference between the total benefits and the cost of the extension project, or some $1.5 million. This sum would be sufficient to support all the activities of the national agricultural survey in all nine departments for about 2 years.

CONCLUSIONS

An estimate of the partial value of recurrent agricultural survey information in Haiti was derived by analyzing a potential investment decision with and without the survey information. It was found that the projected net benefits of a proposed extension project designed to disseminate FSR/E-developed and -recommended practices vary considerably depending upon the information source, the target adoption rate and the discount rate. Under conservative assumptions, it was found that the survey information was sufficient to affect the investment decision and, therefore, had significant value. The value of the national survey information was shown to be the difference between the projected net benefits and the cost of an extension program, calculated using survey estimates.

The results also indicated that, regardless of the discount-rate and adoption-rate assumptions used, the ADS-II project FSR/E research completed to date has significant potential value. However, if this potential is to be realized, extension efforts to raise the adoption rates must be undertaken.

The subject FSR/E project has additional benefits not included in this analysis. The target recommendation domains were limited to monoculture areas in one department in order to synchronize FSR/E, national survey and MARNDR information. A complete definition of the appropriate recommendation domains would include areas in virtually all other departments of Haiti. Also, the recommended practices developed or being developed for crop association, specifically crops, agroforestry, animal husbandry and soil conservation, have been omitted from the analysis. Consequently, this analysis should not be interpreted as a complete evaluation of the ADS-II FSR/E project.

Similarly, the evaluation of survey benefits is also understated. All secondary costs and benefits from the survey have been omitted. It is also clear that the survey information has much more potential value than this one example. A large number of similar project-level problems could be analyzed and decisions modified as a result of this new information. Other survey information, available nowhere else, could be

used to estimate agricultural supply functions, farm income and other macro-level variables of interest to policy-makers. Probably the greatest benefit is the analytical environment established by the survey information system. Such an environment facilitates problem identification and analysis and the development of policy priorities and prescriptions.

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Table 1. Estimated average yields under traditional farming practices and expected percentage increase in yields with recommended practices for the south department of Haiti

Crop	Yield estimates (kg/ha) traditional practices MARNDR[1]	ADS-II[2] survey	Expected % increase in yield with improved practices
Maize	593	680	109
Sorghum	556	710	132
Rice	1221	1400	39
Black beans	475	400	125

[1]MARNDR: Haitian Ministry of Agriculture, Natural Resources and Rural Development.
[2]ADS-II: Agricultural Development Support Project II, National Agricultural Survey.

Table 2. Crop area and yield estimates for the FSR/E recommendation domains, market prices and projected marginal costs per crop with adoption of the recommended practices.

Crop	Hectares		Average yield (kg/ha)		Price (US$/kg)	Marginal cost (US$/ha)
	MARNDR[1]	ADS-II[2]	MARNDR	ADS-II		
Maize	15,097	19,720	593	680	0.360	66
Sorghum	16,485	31,130	556	710	0.446	97
Rice	3,871	7,360	1,221	1,400	0.698	187
Black beans	3,575	5,390	475	400	0.890	0

[1]MARNDR: Haitian Ministry of Agriculture, Natural Resources, and Rural Development.
[2]ADS-II: Agricultural Development Support Project II, National Agricultural Survey.

Table 3. Net present values of an extension program for the FSR/E-recommended practices by adoption rate, discount rate, information source and crop (1986, US$ 000s).

	Discount rate					
	10%		25%		40%	
	MARNDR	ADS-II	MARNDR	ADS-II	MARNDR	ADS-II
50% adoption Rate						
Maize	8,368	13,174	2,281	3,592	1 ,009	1,588
Sorghum	12,535	32,996	3,417	8,995	1 ,511	3,978
Rice	1,819	4,633	496	1,263	219	559
Black beans	6,274	7,966	1,710	2,172	756	960
Total[1]	28,996	58,770	7,905	16,022	3 ,496	7,085
25% adoption Rate						
Maize	4,184	6,587	1,141	1,796	504	794
Sorghum	6,267	16,498	1,709	4,498	756	1,989
Rice	909	2,317	248	632	110	279
Black beans	3,317	3,918	855	1,086	378	480
Total[1]	14,498	29,385	3,952	8,011	1 ,748	3,543
10% adoption Rate						
Maize	1,674	2,635	456	718	202	318
Sorghum	2,507	6,599	683	1,799	302	796
Rice	364	927	99	253	44	112
Black beans	1,255	1,593	342	434	151	192
Total[1]	5,799	11,754	1,581	3,204	699	1,417

[1]Totals may not add up due to rounding errors.

COMMUNICATION ALTERNATIVES FOR FARMING SYSTEMS: A MULTIPHASE PLANNING MODEL

Rosalie Huisinga Norem and Eric A. Abbot[1]

INTRODUCTION

The annual Farming Systems Research Symposium and the Farming Systems Support Project (FSSP) have provided a focal point for practitioners and others to examine the evolving farming systems approach to agricultural development.

A farming systems approach recognizes the importance of an interdisciplinary focus on the constraints faced by limited-resource farmers. It involves the farm household in the identification of problems and solutions. The approach emphasizes the iterative evolution of farming systems building diagnosis and evaluation into projects in order to provide feedback that leads to redesign and improvement through a project's life.

The continuous and complex interaction required between and among scientists, extension staff, farmers and policy-makers using the farming systems approach has focused attention on communication processes and constraints. Not all communication activities require a communication specialist, but all phases of any farming systems project require communication activities. Communication constraints and processes can be studied systematically just as can any agronomic aspect. Communication must be approached as an ongoing process, vital to all aspects of project success, with efforts started at one phase telescoping or "feeding forward" (Bemis, 1985) to subsequent phases.

This paper presents a model identifying communication activities across three phases of farming systems projects to help practitioners identify current areas of communication difficulty and to meet future needs. More specifically, the model helps practitioners decide which communication activities are appropriate under which circumstances at which phase of a project or program. The decision-making guidelines are applicable at any phase of a project. The worksheets (see Appendix 1) are designed to be used to analyze the communication needs of projects in progress as well as in planning new efforts.

A MULTIPHASE MODEL

Numerous sources have discussed specific communication skills and techniques that are important in farming systems (Abbott and Mundy, 1986; Andrew, 1984; Bemis, 1984, 1985, 1986; Benoit-Cattin and Tourte, 1980; Caldwell, 1984; Esslinger and McCorkle, 1985; Goebel et al., 1986; Norem, 1986; and Vierich, 1983). This paper presents a model identifying three broad types of communication activities: diagnosis, training and linkage.

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[1]Iowa State University, Ames, IA 50011, U.S.A.; Department of Journalism, Iowa State University, Ames, IA 50011, U.S.A.

- Diagnosis. A key component of the farming systems approach is diagnosis as an iterative process throughout the life of a project, from early assessment of the constraints facing farm households to evaluation of trials and rediagnosis of the resulting resource/constraint balance. Successful diagnosis relies on communication linking farmers, scientists, extension agents and policymakers into a functioning, decision-making network.

- Training. Recognition of the vital role of training — for example, in how to design and carry out a rapid rural appraisal, how to design on-farm trials and how to be sensitive to the implications of agricultural change for the whole rural system — is a hallmark of the farming systems approach. Communication through training plays a critical role throughout a farming systems effort, strengthening the team effort.

- Linkage. Because farming systems projects are multidisciplinary in nature and because they tie together the expertise and resources necessary to reduce farmers' constraints, they by definition rely on coordination and strong linkages across and between institutional and individual players. Just as projects evolve, linkages also evolve and change through the life of a project.

Figure 1 depicts these three types of communication activities as they are applied during three broad phases of a farming systems project. These activities were selected based on project reports, papers presented at the Farming Systems Symposia in previous years, discussions with farming systems field staff, training experiences and other writings.

Three phases describing the evolution of a farming systems project in stages or phases are well-accepted among farming systems practitioners:

- Organizing. In this phase, teams are assembled, contracts drawn up, objectives established and initial diagnosis activities undertaken. A variety of training needs may be identified at this point. The organizing phase also involves the assessment of the agricultural and communication infrastructure.

- Intervention. After constraints are identified and initial recommendations are developed, the second phase involves activities designed to bring about change in the agricultural system. This may involve changes in farming practices or introduction of new varieties, livestock or a revised marketing system. It is a difficult and challenging process to ensure that farmers have adequate input into development of an innovation, have access to needed inputs and have the means to seek help or provide feedback. Often, increased coordination and training activities both between and within agencies are required.

- New initiatives. This project phase explores the implications of successful adoption of a new agricultural practice. What happens when a project succeeds, constraints are minimized and production increases? It is important to consider what farmers will do next to

build upon this accomplishment and what demands they will then place on extension, research and marketing resources. There are also important implications for the allocation of family labor resources.

[The Farming Systems Research and Extension (FSR/E) component of farming systems has received the most attention over the last few years. Some of the activities included in the grid in Fig. 1 also focus on Farming Systems Institutionalization and Policy (FSIP). Experience from training and projects has blurred the distinction between FSR/E and FSIP, and there is a growing recognition that research and extension efforts often identify constraints that are primarily institutional or policy constraints and that policy decisions determine farming systems research. For example, as Poey (1986) has pointed out, "Lack of effective communication between research and extension institutions in developing countries is often the most important limitation for the successful transfer of technology to small farmers." The influence of top-down decisions was illustrated by Lightfoot and Barker (1986) in their discussion of the interaction between researchers and farmers: "...what ends up being tested are largely the current interest or recommendations of the research institutions."]

THE DECISION-MAKING PROCESS

Several factors influence which communication activities are most effective at various phases. These factors can be addressed with several questions to guide decision-making:

- Which levels of systems should be involved to meet a specific objective?

- Which components of the development and communication context are important at a given point in a project?

- Does communication need to be unidirectional transmission of information or interactional to achieve a specific goal?

- Is the proposed change initiated from within a system level, or is it being initiated externally?

These questions are derived from a few basic communication theory and systems theory concepts. The reader can use the questions as a guide without delving into the theoretical underpinning, but the underpinning was an important part of the process in thinking through which factors should be addressed in making decisions. The concepts of hierarchical systems, contextual analysis and types of changes are briefly discussed in the following sections.

Hierarchical Systems

Studies in the natural and social sciences require careful specification of the unit of analysis. A common practice is to choose a level of analysis then view higher-level systems as environment and lower-level systems as components of the unit of analysis. Mesarovic (1970) pointed

out that each higher level in a hierarchy differs from the level immediately below: higher-level systems are more inclusive, change at a slower rate over a longer time period and are more abstract and, therefore, more difficult to describe and measure concretely. These points are useful in analyzing communications alternatives.

For example, when farming systems practitioners collaborate with farm households to find ways of minimizing production constraints and discover that several of those constraints exist because of credit policies in a region, analysis of these higher-level systems becomes necessary. Usually, credit and other higher-level systems change more slowly than the practitioners and farmers would like. If an initial assessment of the production system includes an awareness of the various levels of systems that are important, credit policies might be part of the planning from the onset of a project.

Training experiences also highlight the need to evaluate and understand the hierarchical levels of systems. For example, numerous participants in intrahousehold case studies training identify institutional and policy constraints as "most critical." These exercises challenge the idea that farming systems projects should be concerned primarily with micro-level production issues.

Contextual Analysis

To the extent that higher-level systems constitute part of the environment for lower-level systems in a hierarchy, they are part of the context in which lower-level systems function and change. Five contextual factors are critically important to understand and analyze farming systems: 1) the institutional context (or hierarchical position), 2) the social/cultural context, 3) the economic development context, 3) the policy context and 5) the disciplinary context.

FSR/E efforts have paid special attention to the social/cultural context, with emphasis on understanding the social and cultural factors that influence farming practices. Intrahousehold dynamics case studies, sondeo methodology and on-farm research efforts all are examples of this emphasis.

Because of the interdisciplinary focus of farming systems, the disciplinary context in which problems are analyzed and solved receives careful attention in farming systems. FSR/E researchers capitalize on the strengths of an interdisciplinary focus but at the same time may be frustrated because scientific advances have encouraged research specialization and a resulting decrease in communication among researchers within and across disciplinary specialties (Abalu and Raza, 1986).

Discussion in the previous section about levels of systems provided examples of how and why the institutional and policy contexts of farming systems work are important.

Farming systems also function within the economic-development context involving donor agencies and host governments. Diagnosis, training and

linkage activities at all phases of a project or program need to proceed with an awareness that FSR/E is part of the larger development arena.

Types of Change

Communication and systems theory identify first- and second-order changes in systems (Watzlawick et al., 1967). Refining intercropping practices in a farming system where crops are already grown together in a field is a first-order change. A first-order change may increase production by reducing certain constraints, but the system remains a cropping system. It does not introduce innovations external to the system. Introducing livestock production into a farming system producing only crops, changing the system itself, is a second-order change. The second-order change introduces innovations from outside the system that may be unfamiliar and less easily understood.

USING THE MODEL AND GUIDELINE QUESTIONS

Figure 1 lists three types of activities appropriate at three phases of a project used in conjunction with the guideline in Appendix 1. The model will assist planners and project staff in identifying potential communication constraints and selecting appropriate activities to minimize those constraints. Possible applications for each project phase in the model follow.

Organizing: Phase 1

Extensive material exists describing diagnosis, training and linkage activities at the early stages of a farming systems project. Consequently, our discussion of communication alternatives for the phase is quite brief. This in no way indicates that careful diagnosis, training and linkage are not important as projects begin. The more thought that can be given to communication needs early on, the better job a team can do of identifying potential communication constraints throughout the project.

- Diagnostic activities: Phase 1. The questions about levels of systems, communication context, interaction and feedback and types of change provide guidance in choosing and carrying out various communication activities at this phase. As the model indicates, project objectives must be determined, target groups identified and participating farmers selected. Concurrently, project staff must focus on an understanding of institutional structures in the region and country. All of this information is taken into consideration in establishing research priorities.

- Training activities: Phase 1. As an FSR team begins to work together on a project, training needs usually become obvious. Team building can make the process of learning to work together and function as a multidisciplinary unit proceed much more smoothly and effectively. If the team is going to do a sondeo, training builds needed skills in interviewing and other rapid reconnaissance techniques.

Specific training materials were developed for each of the activities in this cell of the model plus materials for on-farm trial design and implementation. These materials are widely used. We refer the reader to the FSSP training materials (FSSP, 1986).

- Linkage activities: Phase 1. This is a point at which project staff should be developing a clear understanding of existing communication channels between and within the groups involved with their project. If careful assessment of institutional structures is a part of the diagnostic activity for this phase, information about which linkages are most critical should be obtained. As stated earlier, linkage building is a constant, evolving process. Networks established now will facilitate work during later stages of a project.

Intervention: Phase 2

Implementation begins when tentative solutions are identified and a team becomes more concerned with disseminating information about innovations beyond the initial farmer-participants. Policy and overall development planning issues may have to be addressed at this phase. The scope of a project tends to broaden its focus during this phase.

- Diagnostic activities: Phase 2. As the project focus shifts from the organizing phase to intervention, new issues arise: how to incorporate recommendations into research, extension and communication systems aimed at a broader audience. Typically, existing feedback systems from farmers and extension agents to researchers, marketers and policymakers are weak or nonexistent. While FSR/E projects have made some progress in improving feedback systems with participating farmers, feedback requires attention throughout a project. Thus, a key diagnostic activity is to develop an ongoing, low-cost but effective feedback system to assess how farmers are changing their agronomic practices, how economic factors are influencing the production and marketing of existing or new crops and how extension and research agencies are meeting their new responsibilities.

  Questions about system levels, direction of communication and context are especially important to diagnostic activities. Acker and Sungusia (1986) presented an example of the influence of institutional context. In their discussion of the Tanzania farming systems research project, they reported that even though the original project statement of purpose recognized the importance of extension, the project was based in the research organization. There was no formal collaborative agreement with extension, and no extension personnel were assigned to the FSR teams. A diagnostic activity used by the team included a survey investigating the potential for increased extension participation.

  In general, the strength of farming systems projects has been their ability to involve researchers and other disciplinary specialists in the process of monitoring implementation of project recommendations. Feedback has also been useful in pinpointing inter- or intra-agency

communication weaknesses, although solutions have been more difficult to achieve. However, the training and networking activities discussed below may suggest alternative solutions.

- Training activities: Phase 2. At the intervention stage of a project, farmers must be alerted to new recommendations or opportunities that have been developed in collaboration with participating farmers. All available communication channels must be mobilized for this purpose to achieve the best results. Generally, little attempt is made in projects to tie together mass media messages (radio, television, mobile vans, posters, brochures and other printed materials) with the interpersonal efforts of extension agents or other field workers. Farming systems projects tend to emphasize interpersonal contacts.

  To maximize communication effectiveness at the intervention stage, two types of training are needed. Communication planning and strategy must be developed. Staff with responsibility for extension messages and mass media production must learn how to plan and implement a coordinated information campaign suitable for farmers in the area. Skills in understanding and taking advantage of the cumulative nature of communication effects from one medium to another, methods of scheduling messages for maximum impact and techniques for budgeting at minimum cost are essential but are not commonly found among project staff. Training in information transfer skills can be critical if these efforts are to be used successfully.

  The second type of training involves specific communication media skills. Many extension agents and researchers have excellent skills in designing an on-farm trial but poorer skills in how to attract people to see and understand the message derived from trial results. A combination of posters, flipcharts, handouts, flags and other devices can attract a larger audience and achieve a greater impact. These skills can be taught to field-level extension staff rapidly with use of locally available materials at very low cost.

- Linkage activities: Phase 2. As a project moves from the organizing phase to the intervention phase, additional agencies and organizations necessarily become involved in the project. It is necessary to build linkages between field staff and higher policymaking agencies as the implications of project recommendations for production and the national implications of marketing activities begin to be understood. Questions about system levels, context and interactions need to be reexamined.

  Linkage problems between agencies have been documented frequently in previous reports. Caldwell et al. (1986) noted that attempts to coordinate activities of agricultural and home economics extension often proved futile. In Thailand, the linkage problems between research and extension became so serious in one project that a full-time person was assigned "to examine a better approach in technology transfer and ways to improve linkage between research and extension (Charoenwat ana, 1986). Writing about Indonesia, McIntosh (1986)

discussed the lack of a strong private sector in many developing countries and the importance of public institutions making great efforts to institutionalize and develop technology flow and feedback.

This pattern of increasingly complex linkages can be anticipated in a project. Therefore, it should be planned for in advance. It is important at this phase to recognize that linkage problems are likely to occur and that special attention should be given to monitoring linkages to ensure their effectiveness. Both media and interpersonal linkages are important. Citing an example from Nigeria, Spring (1986) noted the failure of publications to link research with extension and farmers. Similarly, McIntosh (1986) pointed out the importance of "informal contacts and cooperation" between field research and extension.

Another aspect of the linkage issue that has received a great deal of attention at the intervention stage is links with donor institutions. International agencies and regional agricultural organizations are also important during the intervention phase. Various sources have discussed the importance of these linkages in the cultural context of Africa (Bernsten et al., 1984), Latin America (Mateo and Li-Pun, 1984), and Asia (Price and Acebedo, 1984). These linkages provide an additional means of sharing experiences among FSR/E projects. These linkages are crucial, providing field staff with information on problem identification and solution.

From its inception the farming systems approach has emphasized interdisciplinary teams and activities. While different groups, more complex hierarchies and additional communication contexts may be involved, the communication activities used to link interdisciplinary teams in the organizing phase may serve as a model for the intervention stage.

New Initiatives: Phase 3

What happens when farmers begin adopting FSR/E project recommendations that reduce key constraints? What happens when the farming systems approach succeeds? This phase raises special diagnostic, training and linkage issues that require "new initiative" communication activities. This phase often involves not only first-order change in agriculture, utilizing existing crops and inputs, but also second-order change, involving marketing systems or even new industries. Consequently, it is important to recognize system levels should be involved to meet specific objectives.

For example, when a farmer begins to produce adequate food — or even a surplus — his or her interactions with higher-level agricultural systems become much more complex and challenging. There will be new and additional demands for information.

During this phase, agricultural product processing centers, export agricultural businesses and family cottage industries may develop. The

economic development context may change. Very often the extension and agricultural research staff recruited for the first phases of the FSR/E project are not the most effective individuals during the new initiatives phase. The disciplinary context may also change, and new interactive communications patterns must be initiated.

An integrated rural development project near Portoviejo, Ecuador, provides an example of the chain of events that may occur in the new initiative phase. An improved cassava variety was recently introduced into the area following an extended diagnostic phase. The result was a significant increase in cassava yield. At that point, farmers with surplus production needed links to marketing and processing opportunities. The United States Agency for International Development (USAID) provided a loan to construct a concrete drying slab and a cassava chip grinding machine. Contacts were made between farmers and a private cassava chip firm in Guayaquil. Contractual arrangements were made with the firm and with trucking firms. Later, representatives of an export firm trained farmers to select and package the best cassavas for export. As a result, many farmers elected to remain in the area during postharvest processing instead of migrating to cities to seek work. Their wives and children began developing cottage crafts industries. As an unintended by-product, the farmers learned how to ferment the cassava into a potent alcoholic drink, creating additional processing opportunities.

Once the cassava farmers learned how to produce, process and market the new varieties of cassava, they began to exchange information with nearby farmers who were interested in copying their success. These farmers had the potential to- become trainers, businessmen and agents for other farm communities as well as their own. Changes that started as pretty much internal to their farming systems mushroomed to initiate changes in several other system levels. Communications was a critical, dynamic component of this process (Abbott, 1987).

Several lessons important for "new initiatives" in farming systems can be drawn from these examples. In each case, it is clear that the types of information necessary, the persons and expertise necessary and the level of communication are substantially different from the usual communication context. It is also apparent that outside linkages and involvement may be essential for further development activities to take place.

- Diagnostic activities: Phase 3. In the new initiatives phase, it is not always clear who should be responsible for communications activities. Providing technical advice, or perhaps even inputs to farmers, is an explicit public sector responsibility. On the other hand, marketing, exporting and processing may be activities of the private sector, cooperatives or associations. Identifying relevant private and public sector businesses and institutions to provide these crucial market linkages is a key diagnostic activity. Diagnostic activities may also involve identifying policy and institutional constraints.

Assessment at this point does not necessarily involve a complex organizational inventory of a country. Information gathered at earlier stages can be updated through the general approach already developed by farming systems research — a focus on constraints.

An expanded disciplinary focus may be helpful. A private sector specialist familiar with market analysis, contracts and transportation might be essential. Food technology or storage specialists might also be needed. A specialist in organizational networking with knowledge of the project country's communication and decision-making system would be valuable, if that expertise is not already on the team.

- Training activities: Phase 3. The widening spectrum of networks needed to carry out new initiatives involves agencies and organizations that may not have been previously involved in a farming systems project. This often means that policymakers, planners and others who allocate scarce resources must become project audiences. Compton, in discussing the farming systems development project — Eastern Visayas, identified the need for "integration, regionalizational, and institutionalization of FSR and FSE" (1986). The project responded with a shortcourse for provincial and district administrators, extension specialists, researchers, university faculty and regional staff. This is an excellent example of network training including new audiences as the need for institutionalization is addressed.

  New initiatives often bring with them the need for additional local educational or technical job training. With processing, cottage industries or other employment opportunities comes the need for literacy as well as recordkeeping and stronger communication skills. Multidisciplinary and multiagency involvement is critical to proper identification of training needs and their implementation.

- Linkage activities: Phase 3. Farming systems practitioners often express frustration at the number of organizations and institutions with which they must deal to coordinate field activities and national policy. A survey of farming systems projects undertaken by a FSSP communications task force in 1986 found that projects with their headquarters in the field often mentioned coordination with national institutions as a problem while those projects located in the capital identified coordination with field practitioners as an important problem.

  Realistically, the need for coordination can only be expected to increase as new initiatives are undertaken and new segments of the economy and regions of the country are involved. Second-order change explicitly requires new linkages between organizations and other sectors of the economy. Effective use of media efforts and careful attention to interpersonal networks are essential elements in meeting these challenges.

SUMMARY

This paper presents and discusses a model designed to facilitate identification of communication needs in FSR/E projects. Three types of communication activities — diagnosis, training and linkage — are discussed as they apply to the organizational, intervention and new initiative phases of farming systems.

The ideas from the paper were used to design worksheets presented in Appendix 1. These worksheets provide a starting point for systematic assessment of the communication process throughout a project's life.

Each development phase offers a wide opportunity for mass and interpersonal communication activities. This paper illustrates ways in which existing research and extension efforts can be linked to public and private sector institutions to maximize opportunities for farm households to take advantage of agricultural innovations and information.

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Fig. 1. Multi-phase activity planning, implementation and networking grid.

TYPES OF ACTIVITIES	DEVELOPMENT PHASE (PROJECTS, PROGRAMS, OR OVERALL DEVELOPMENT EFFORTS)		
	ORGANIZING	INTERVENTION	NEW INITIATIVES
DIAGNOSIS	identification of project objectives identification of target farmers identification of participating farmers assessment of existing group structures setting research agenda identification of policy makers relevant for project, program, etc.	social-cultural analysis economic analysis agronomic analysis feedback process evaluation and revision of intervention efforts	assessment of alternatives for auxilary efforts market analysis processing potential analysis impact analysis community development needs
Training	team building interviewing skills secondary data analysis utilization intra-household analysis case studies inter-disciplinary work language training training for trainers data management skills	workshops for policy makers media use training information transfer training seminars re. projects or programs (for donors, ministry personnel, others) network analysis training	community improvement self-help skills training literacy education health education planning workshops continued networking training for researchers, extension, private & public sector representatives
LINKAGE	identification of existing communication channels community infrastructure assessment networking with other projects and programs (private & public sector) identification of media use patterns literacy assessment	getting information into channels ongoing community involvement building community linkages and inter-group cooperation farmer-farmer liason with policy makers farmer-extension liason with donors farmer-researchers technology transfer extension-research ongoing networking with private and public sectors	media efforts farmer groups networking: private-public sector

prepared by Rosalie Huisinga Norem and Eric A. Abbott
December, 1986

APPENDIX 1

WORKSHEET ON USE OF THE MODEL IN PROJECT DECISION-MAKING

An abbreviated version of the worksheet is presented here applying the elements of the model to decision-making needs of farming systems projects. A more elaborate version is available by writing the authors.

Steps in Using This Workshop for Your Project

1. Identify your project's phase of development in one or more cells of the model. Would you say it is in the organizing, intervention or new initiatives phases?

2. Use the guiding questions presented in the paper to pinpoint important features of your project that are relevant to your communication needs.

   - Which levels of systems are currently involved to meet your project's objectives? (field, local, district, regional, national, international)

   - Which components of the development and communication context are important at this point of your project? (social/cultural context, economic context, policy context, marketing context, etc.)

   - To meet project objectives, does the communication between levels or across contexts need to be unidirectional or bidirectional?

Is the change (or changes) that the project is attempting to identify and implement initiated from within a system level or is it being externally initiated? (What institutions will need to be involved in bringing about those changes?)

3. Using techniques similar to those of a sondeo, identify important communication constraints and problems your project currently has. (Rather than attempting to study all aspects of communication in your project, focus on those that are currently causing the most difficulty.)

4. Identify alternatives for dealing with your most important communication problems. It may be helpful to analyze how previous communication problems were solved by your project at a different phase, or how other projects in the area addressed similar problems. Can some of the organizing, training or linkage activities suggested in the paper help solve these problems?

5. Act on several of the most important problem areas, and then evaluate to what extent project performance is improved.

6. It is recommended that you repeat the process outlined above <u>projecting</u> your communication needs for the next 1-3 years.

PROJECT WORKSHEET

Your Project Phase_____

Diagnosis Activities:

a. Communication problems or constraints across levels, within or between communication contexts, etc. Problems with top-down or bottom-up communication efforts; constraints caused by the need for more agency or higher-level agency activity.

_____

_____

b. Alternatives for solving the problems or constraints identified in (a).

_____

_____

Training Activities:

a. Training problems or constraints across levels, within or between certain communication contexts (between farmers and extension, extension and research, project and policymakers, etc.). Problems with training to achieve bottom-up communication; problems in training other agencies in project objectives and methods.

_____

_____

b. Alternatives for solving the problems or constraints identified in (a).

_____

_____

Linkage Activities:

a. Problems or constraints in linkage at various project levels (farmer-extension-policymaker-donor).

_____

_____

b. Alternatives for solving the problems or constraints identified in (a).

_____

_____

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ASSESSMENT OF THE IMPACT OF FARMING SYSTEMS RESEARCH IN SELECTED ASIAN COUNTRIES

N. F. C. Ranaweera and R. R. Gonzaga[1]

INTRODUCTION

Farming systems research (FSR) has been the most discussed and researched area in the agricultural research system during the last decade and a half. With the concept of "on farm" research and "whole farm" approach as well as moving away from the traditional monocrop strategy, researchers in the developing world spend large amounts of resources to formulate and test programs in the field. More recently multilateral and bilateral funding agencies have funded farming systems research programs. Bernsten (1982) stated that "...increasingly resources earmarked to accelerate international agricultural development are being allocated to support research activities that are described as following a farming systems research and development approach."

This increasing interest in farming systems research has been due in part to concerns regarding the effectiveness of previous monocrop-oriented research strategies. The technology developed for maize, wheat and rice revolutionized food production strategies in the Third World. Although food production has increased, the new technologies have raised concern about the benefits farmers have received.

Conceptually, FSR emphasis is on "whole farm" approach, but in practice (particularly in the Asian region) research has focused on component technologies relating to specific crops within a farm, such as crop varieties, sequence of crops or the introduction of new crops. Consequently, some national programs referred to this research strategy as "cropping systems research (CSR)."

Some farming systems research programs in Asia have been successful. Hoque (1984) identified successes in rainfed and irrigated areas at Bogra in Bangladesh; McIntosh (1985) described the gains made in Indonesia under both rainfed and irrigated conditions; and Fernando (1979) described the progress in the minor tank irrigation areas of Sri Lanka. Additional successes in crop intensification have been recorded in Thailand, and the technology developed in the Iloilo province of the Philippines for rainfed conditions has been extensively adopted by farmers (Quisumbing, 1983).

With the maturity of these programs, several questions arise. Has the technology developed within the FSR framework had the desired effects, and have the farmers benefited?

Several questions need to be addressed:

- What are the benefits of the FSR approach?

[1]Visiting scientist and research assistant, respectively. Agricultural Economics Department, IRRI, Los Banos, Laguna, Philippines.

- Have real incomes and purchasing power of farmers increased?

- Have the adverse conditions facing the farmer been reduced or eliminated?

- What effect has the FSR approach had on research management?

- Have supporting institutions such as extension, credit, marketing and input supplies responded to the new approach?

- Have policymakers geared agricultural policies toward a farming systems research framework?

- Is the FSR approach the way to spearhead agricultural development programs in the future?

IMPACT STUDIES — PREVIOUS EXPERIENCE

Several attempts have been made to undertake impact studies of cropping systems research. Price (1982), assessed the impact (in Iloilo, Philippines) of increased cropping intensities on farmers' incomes. Ranaweera and Siripala (1982) and Ranaweera (1983) examined the impact of new cropping systems technology under minor tank conditions in Sri Lanka. Van der Veen (1983) examined the adoption rate of new technologies in Nepal, while Djauhari (1983) undertook similar studies in Indonesia at Bandarajaya, Batumarta and Way Abung. Barlow et al. (1983) incorporated income-expenditure patterns in evaluating the adoption of new technologies on rice farms in the Philippines.

A major problem facing researchers who conduct impact studies involving production-consumption and nonfarm activities is the availability of an accepted methodology that can easily be adapted to individual country situations. Added to this is the difficulty of measuring certain parameters. The complex interaction between production and consumption activities on family farms, along with problems relating to nonadditive utilities, further compounds the problem. As Anderson (1985) stated, further complications arise by "...the multiple attributes by which agricultural households judge their achievements and the multiple constraints and technological relationships under which they operate, as well as the several challenging tasks of aggregation, over research projects, target farms and time, and of accounting over individuals and markets."

The most common methodology used by researchers is cost and return analysis, which is a partial budgeting technique. Studies by Price (1982) in the Philippines and Ranaweera (1983) in Sri Lanka used costs and returns. Wangwacharakul (1984) used an input-output model to analyze the impact of cropping systems technology and irrigation on output, incomes, imports and employment in two provinces of Iloilo in the Philippines. Mathema (1986) used a production function to analyze the impact of cropping systems research in Nepal. Production functions have also been used to measure frontier performance and technical

efficiency of innovative and noninnovative farmers in Sri Lanka by de Silva and Shand (1986).

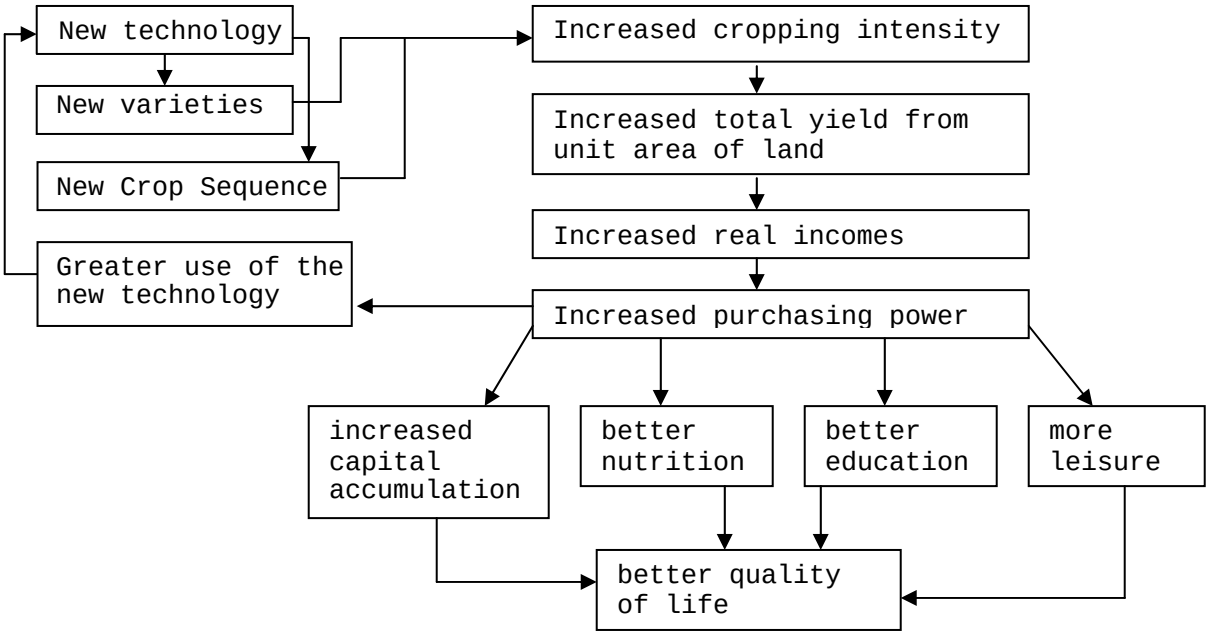
Another methodology used is linear programming (LP). Jayasuriya and Price (1980) enumerated a number of advantages of LP techniques over others and also discussed some of the difficulties in dealing with values of certain parameters. Barlow et al. (1983) used an LP framework to analyze the impact of cropping systems research in the Philippines.

Moreover, production-consumption and nonfarm activity need to be viewed holistically, with special attention to off-farm income, nonfarm activities and the home garden.

A study in Bangladesh, Indonesia, Philippines and Sri Lanka is monitoring all activities of the farm (production-consumption and income generation) in order to analyze interactions between technology adoption and nutrition, education and capital accumulation. Final analysis is scheduled for early 1988.

OBJECTIVE OF STUDY

The ultimate aim of FSR is to increase the "quality of life" and improve the well being of the farmers. This is schematically presented as follows.



The diagram indicates where the benefits could be obtained and identifies parameters to be measured. A farm household's income can come from the farm, outside sources and home garden production. A careful monitoring of the sources of income and expenditure patterns as well as an analysis of the interplay of the resource base with consumption and other activities can provide insights on the impact of new technology.

There is a need to assess the influence the FSR approach has had on the general research structure. Also it is essential to know how well

supporting institutions have responded to this new approach. Policy implications for the future direction of FSR could be drawn from a study of these issues.

The specific objectives of this study are to:

1. Determine the degree to which new technology has increased real incomes and the purchasing power of farmers.

2. Measure the degree to which the increased purchasing power has increased nutritional and educational levels of farm families and capital asset accumulation.

3. Examine the influence FSR has within the national research systems and the impact it has had on research management and policy.

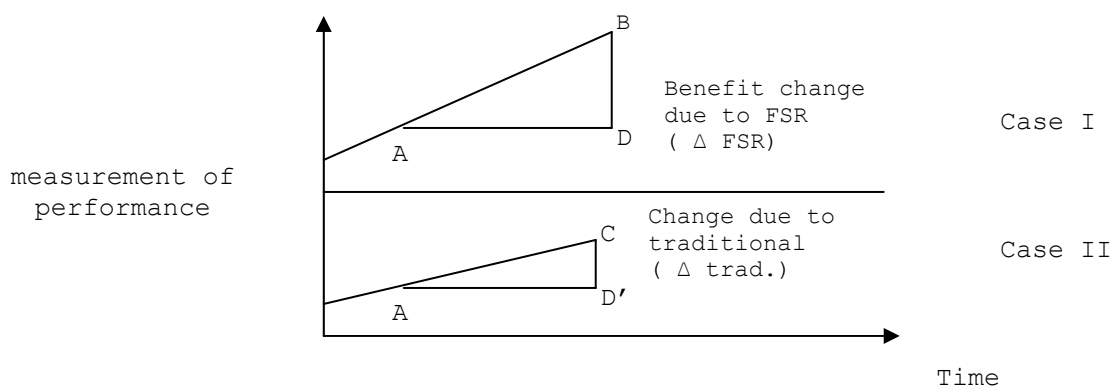
4. Study the role support institutions play in responding to the new technology package.

5. Recommend policy directions that could influence the future role of FSR activities.

6. Develop a cost-effective but robust methodology to measure the impact of FSR research programs that can be used by national programs that have access to a microcomputer.

There are two approaches to analyzing the impact of FSR. They differ mainly in their data requirements. With a cropping systems program, a before-and-after approach has the disadvantage that a measurement of increase due to natural growth is difficult to obtain, while in the with-and-without approach, an assessment of the situation in the same period as the FSR program was introduced is difficult to measure.

The two approaches are graphically illustrated below.



What is assumed in the study is that a change in FSR minus a change in traditional practices equals the net benefit due to FSR. The problem is

to obtain measures of a change resulting from FSR and a change resulting from traditional practices.

In case 1 (before and after), point A can be easily measured. Point B too can be measured, and hence FSR is measurable.

However, in case 2 (with and without), point A is difficult to measure, although point C can be measured.

SAMPLE SELECTION

The following steps were followed in sample selection.

1. Villages in which many farmers had adopted the new technology were identified within a region, municipality or district. Adoption measures were obtained from extension staff and other institutions responsible for implementation of projects.

2. The secondary data were examined for selected villages. From the selected villages, data pertaining to farm size and other factors were examined to determine the homogeneity of sociocultural factors In addition, information on varietal use, yield per hectare, extension activities, input use, marketing arrangements, credit issues and other institutional arrangements were also obtained to provide a general description of agriculture in those villages.

3. If there was considerable variation in farm size, farmers were stratified according to farm size to indicate the effect of farm size on the adoption of new technology. After stratification, farmers were selected randomly under the farm size categories. If the farm size was homogeneous, then the sample was selected randomly.

4. Population was classified according to adopters and nonadopters:
   Adopters — farmers using technology over 3-4 years
   Nonadopters — farmers not using technology presently

5. If any of the selected farmers refused to cooperate, alternate farmers were selected.

DATA COLLECTION

Data collection consisted of daily monitoring of all production and consumption activities as well as income obtained and sources of income including income from the home garden. The data collection format was composed of three forms. Form I is a household inventory; Form II, production activity record; and Form III, daily monitoring of household expenses. (Appendix 1 provides Forms II and III.)

A menu-driven program using dBase III+ was developed to record and analyze the data (F0XBASE+, which is more powerful and 100% compatible

with the dBase III+, is being used in one site in the Philippines). The system developed is designed to accommodate future expansion.

The screen formats were designed to resemble the data entry forms used in the sites. Initial validation was undertaken during data entry. A more rigorous data validation process can be done immediately after data entry or at any convenient time after the data has been entered (usually during break periods since user's assistance is not necessary).

The large amount of data being collected, income and expense data in particular, made the data management software less efficient. To achieve greater efficiency and speed during data processing and initial analysis, subfiles were created from the master file beforehand.

Only the most commonly used aggregation procedures and data transformations were built into the program. The rest can be done outside the program, using the facilities of dBase III+. In general, the system was designed to facilitate data entry, editing, validation and initial analysis. The primary purpose of using dBase III+ is to help the researcher prepare his data so appropriate statistical software can access them. Figures 1 and 2 and Appendix 2 indicate the flow charts used as well as a sample of the data output.

Once the individual country parameters are identified, the data will be aggregated to permit analyses.

Discriminant function analysis will be used to identify the variables that differentiate the adoption of the new technology between adopters and nonadopters. Important variables that will be tested are fertilizer quantity, labor and seed use.

METHOD OP ANALYSIS

Empirical Model — it is hypothesized that within a whole-farm framework

$$TI = I_t + I_0 + I_s$$

where

TI = total income
I_t = income from farm activities
I_0 = income from off-farm activities
I_s = income from other sources

If $I_t > I_0$ and $I_t > I_s$, then income from farm activities is predominant.

If, however, $I_t \leq I_0$ and $I_t \leq I_s$, the farm income is less significant to the household.

In two populations of adopters and nonadopters, if I_t (adopter) $\leq$ I_t (nonadopters), then the new technology has little effect. Additionally,

$$W = f (I, E, C, S)$$

where

W = welfare of farm (this is defined as an index of education, nutrition and consumption
I = total income
E = educational level
C = consumption
S = savings.

Moreover, it can be stated that

$I = f (It, I_0, I_s)$
$C = f (I, E, S)$
$E = f (I, S)$.

This system of simultaneous equations can be solved using two stage least squares method. Estimates of total welfare for the two groups can be measured after the use of appropriate weights.

CHARACTERISTICS OF INDIVIDUAL COUNTRY SITES

Below is a brief outline of the characteristics of each of the country sites and the objectives of the individual studies.

Bangladesh

Two sites are operational. They are located at Sitakunda Upazila in the Chittagong district and Kamalganj Upazila in the Moulvibazar district. Both sites used traditional varieties until new cropping systems technology developed at Bogra, near Joydebpur by the Bangladesh Rice Research Institute (BRRI), was introduced. The old and new technologies are schematically presented in Fig. 3. Here the technology consists of introducing new varieties of rice.

At the Sitakunda site, the new technology consists of

- new rice varieties
  BR1 - BR14
  BR14 - BR10
- use of basal fertilizer
- changes in the method of planting.

At the Kamalganj site, a pilot production program was introduced in 1982 where new high yield varieties (HYVs) were introduced. At present almost 70% of the farmers are using HYVs. The approach is similar to that developed in Bogra.

Indonesia

In the site at Bone, Band Ache, North Sumatra, wetland rice has been the traditional crop under rainfed conditions, and the rest of the year the land was fallow.

The cropping systems program introduced several new food crops and found soybean most successful. The area planted to soybean in Band Ache increased from 19,000 ha in 1980 to almost 85,000 ha in 1985. The current cropping pattern at the site is predominantly rice-soybean.

The soybean crop yields have been substantial (1.4 t/ha) and the prices paid to farmers also high, thereby resulting in high farm incomes.

The old pattern is rice-fallow while the new pattern is rice-soybean-fallow, as seen in Fig. 3.

Philippines

Two rainfed sites were selected in Region VI in Iloilo province. One site is located in the municipalities of Oton and Tigbauan where the original cropping systems research was conducted by IRRI from 1975-1980. The old technology consisted of a single crop of rice under rainfed conditions using traditional varieties. The new technology introduced short-duration, photoperiod-sensitive HYVs, which enabled farmers to obtain two crops of rice and sometimes a third crop of other field crops (Fig. 3). This technology was introduced widely in Iloilo province and formed the agricultural base of the World Bank-funded Kabsaka project.

The second site is in the municipality of Ajuy. Ajuy is a relatively large municipality composed of 34 barrios, 3 of which are island barangays. Initially, nine barrios were selected based on the following criteria: 1) rainfall as source of irrigation water, 2) landscape position generally flat and 3) soil type evenly distributed throughout the area.

A complete list of the farmers from the nine barrios was secured from the municipal office of the Department of Agriculture. The list showed the adopters and nonadopters and the corresponding farm sizes of each farmer. The number of barrios included in this study was three: Pili, San Antonio and Culasi.

Stratified random sampling was used to select the sample respondents. First, the distribution of rainfed farmers by barrio and farm size was determined. Second, the number of adopters and nonadopters in each farm size category was noted after which the 60 farmer-respondents were selected using the proportional-to-size allocation method. The sample size was limited to 60 farmers due to financial and manpower constraints.

Farms were categorized by size (1-1.99 ha, 2-3 ha and greater than 3 ha) to determine if there were significant differences in the degree of technology adoption among rainfed-rice farmers belonging to different farm size groupings.

For the impact study, five barangays were selected from which a total of 58 farmers are being monitored. The rationale for selection of this site was to estimate the impact among the initial farmers selected for the cropping systems research.

Sri Lanka

In Sri Lanka two sites have been selected for study in areas that have been conducting the cropping systems research for over 6 years.

The first site at Katupotha, in the Kurunegala district, has had cropping systems research since the inception of the program in Sri Lanka in 1976. Katupotha is in the Intermediate Zone of the country where over 60% of the paddy land comprising around 40,000 ha is left fallow during the second season due to insufficient rainfall for paddy cultivation. Field research over the past 5 years has clearly shown that grain legume can be cultivated very successfully with the incident rainfall; 55- to 56-day legumes appear to be most suitable. Mungbean is preferred to cowpea due to the higher price obtainable. Early planting of mungbean reduces the incidence of mosaic virus significantly.

The farmers' practice had been a two-crop pattern with a possible third crop. This crop pattern entails: 1) the risk of crop loss due to rain at the tail end of the third crop, 2) inability to plant the rice crop on time and 3) absence of grazing lands for cattle. Considering all factors, a two-crop pattern may be more beneficial. Although the rice-potato-bean combination gives high income, more farmers prefer only two crops.

The second site is at Uva Paranagama in the Badulla district. The site has been operational since 1980. The new technology developed consists of providing an early-maturing variety of rice followed by two other nonrice crops. The farmers' pattern has been a two-crop pattern with a possible third crop. At both sites data are collected from 60 farmers (adopters and nonadopters).

Special studies will be undertaken at each site to assess support service institutions (extension, credit, marketing) involvement as well as the impact of FSR on the research systems. These studies will provide information that could help policymakers to better respond to farmers' needs and also evaluate the real merits of FSR.

SUMMARY

This study attempts to measure the impact of farming systems research as confined in a sense to the rice-based program in four selected countries in Asia. The data collection and analysis have been developed with a view to use of microcomputers since that is about the level of technology most national programs could attain.

The data monitoring formats have been developed to reflect all production and consumption activities as well as sources of income. The

analysis will reflect the degree to which the technology contributes to the well being of the farmers.

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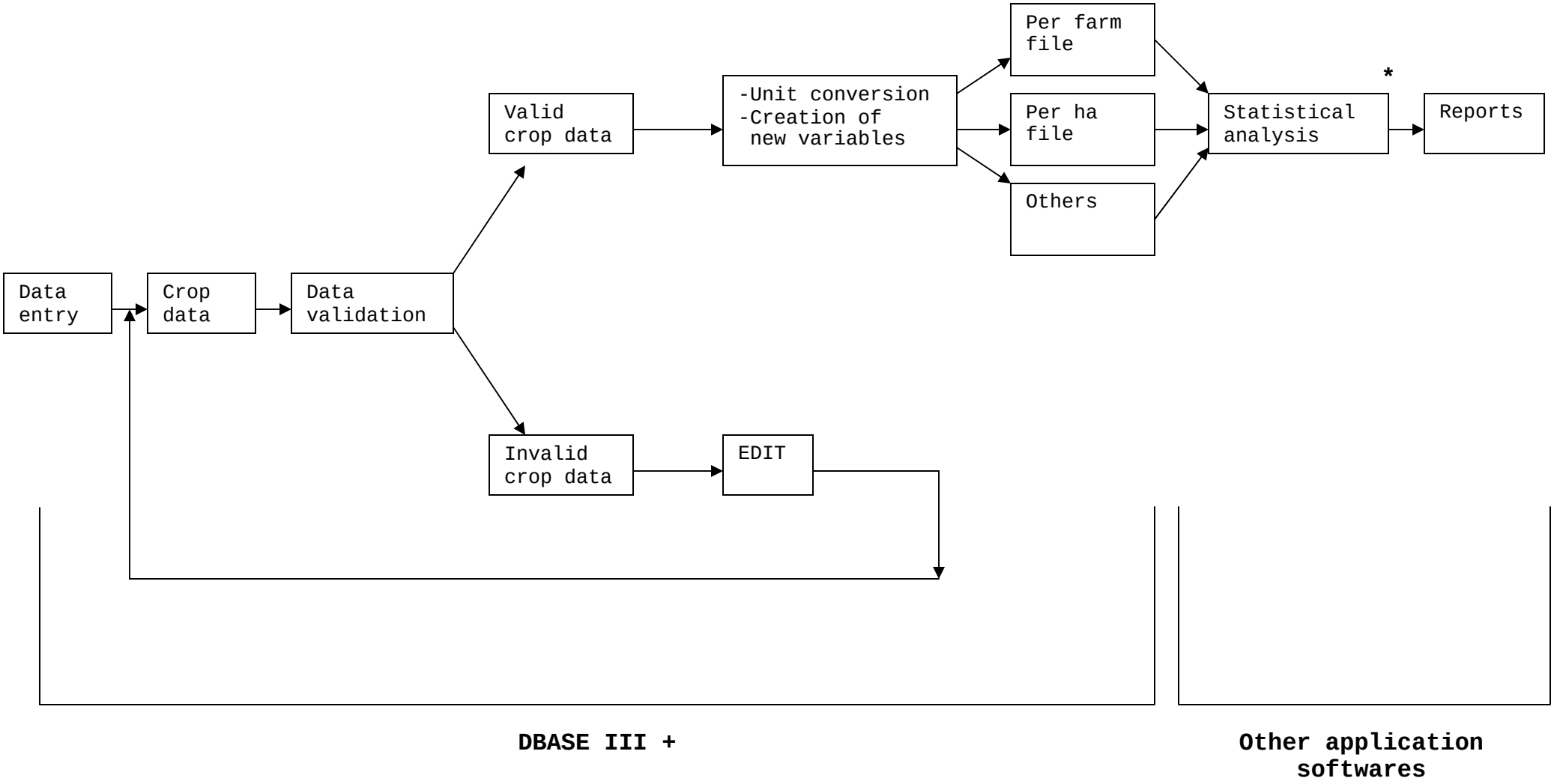

Fig. 1. Crop production data flow.

*** microstat, lotus 1-2-3, SAS, etc.**

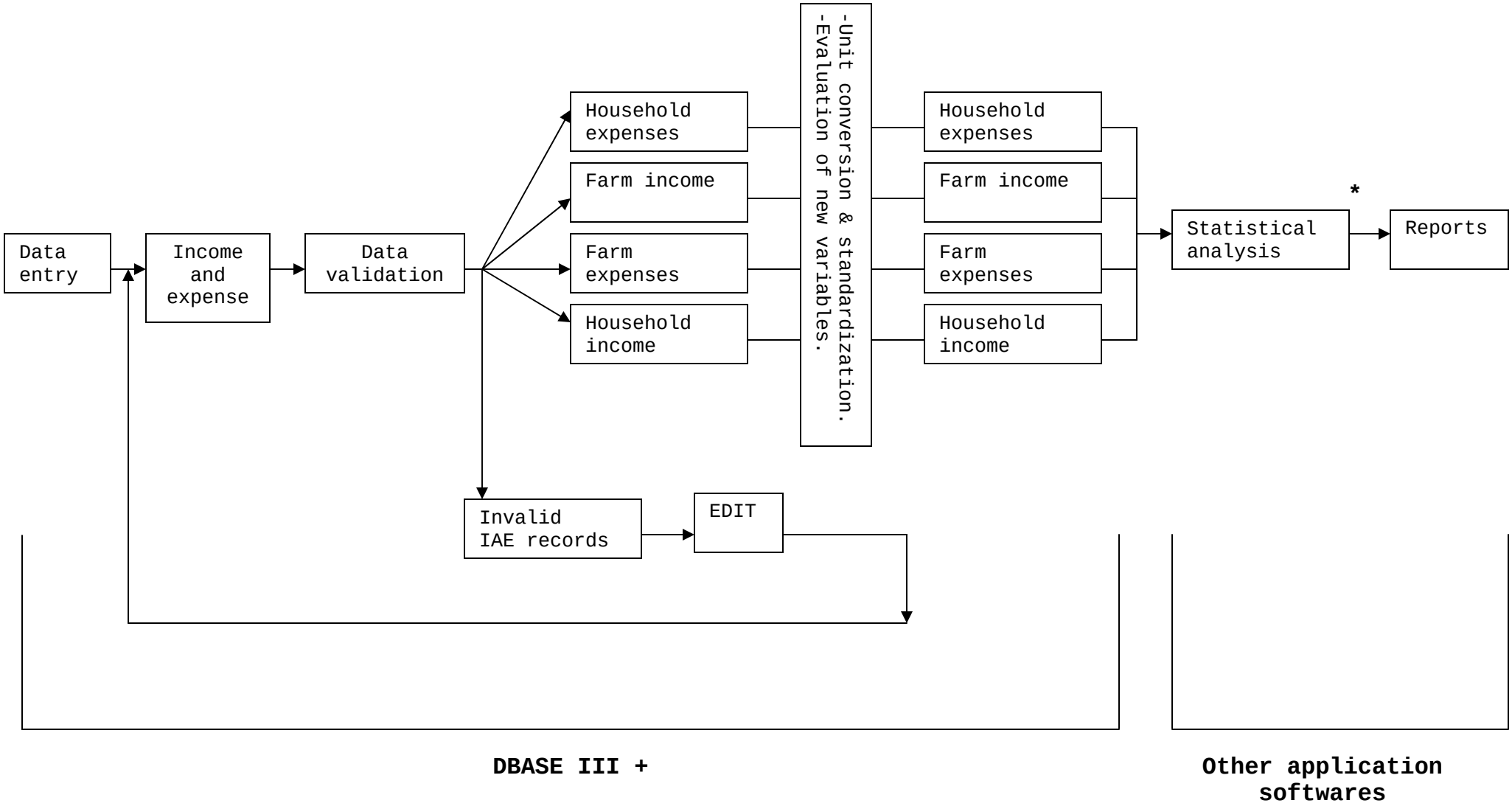

Fig. 2. Farm-household income and expenses data flow.

*** microstat, lotus 1-2-3, SAS, etc.**

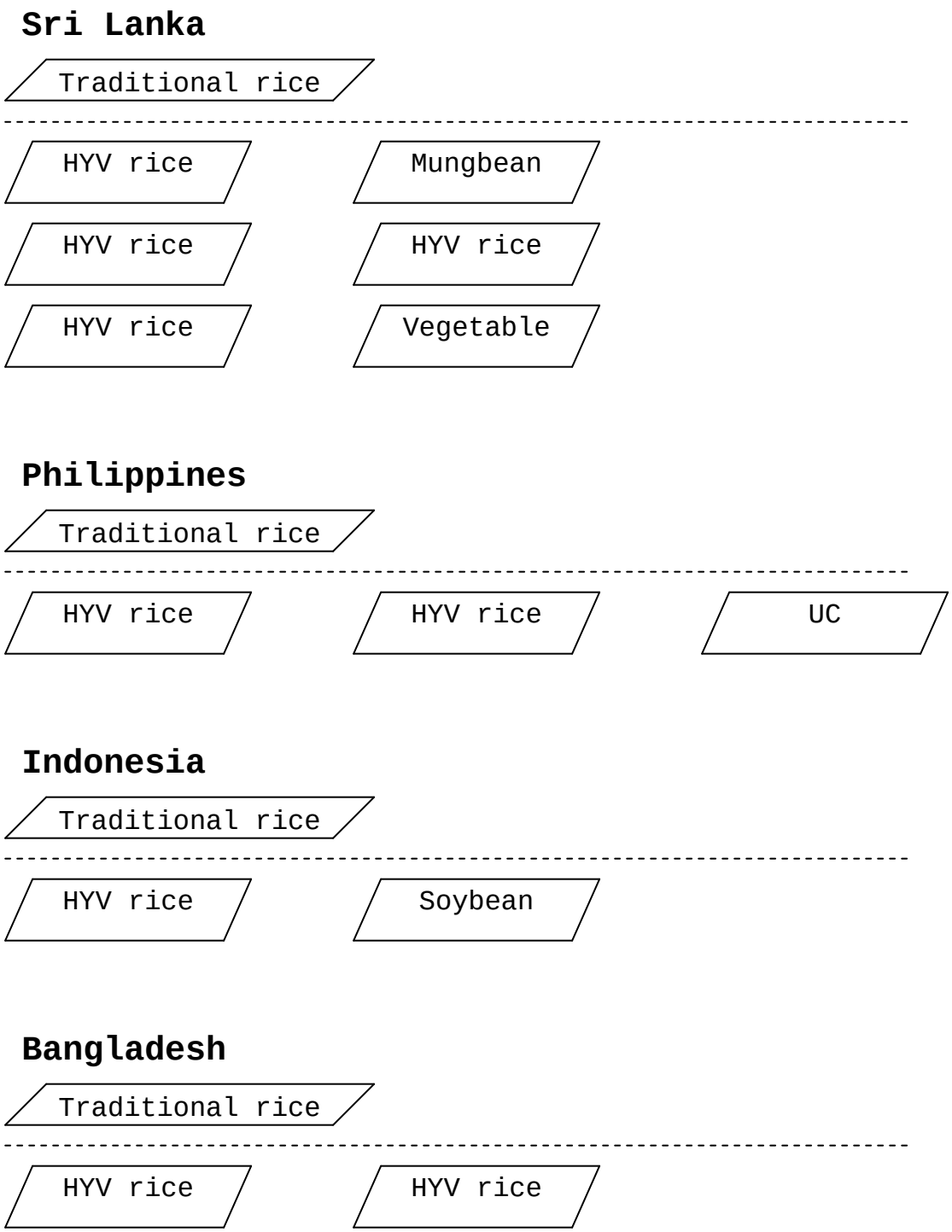

Fig. 3. Changes in cropping patterns.

Appendix 1.

Farmer Number _____

Inclusive Week ____/____/____
mm dd yy

Field Aide _____
Input Date _____
No. Records for Week _____

Weekly Farm-Household Transaction
Cash and Non-cash

Transaction	_____	_____	_____
Payment Mode	___	___	___
Value	_____	_____	_____
Quantity	_____	_____	_____
Source	___	___	___
Remarks	_____	_____	_____
Transaction	_____	_____	_____
Payment Mode	___	___	___
Value	_____	_____	_____
Quantity	_____	_____	_____
Source	___	___	___
Remarks	_____	_____	_____
Transaction	_____	_____	_____
Payment Mode	___	___	___
Value	_____	_____	_____
Quantity	_____	_____	_____
Source	___	___	___
Remarks	_____	_____	_____
Transaction	_____	_____	_____
Payment Mode	___	___	___
Value	_____	_____	_____
Quantity	_____	_____	_____
Source	___	___	___
Remarks	_____	_____	_____

Appendix 1. Weekly Crop Production Activities

Farmer No.		:	___ ___ :	___ ___ :	___ ___:
Plot No.		:	___ ___ ___ ___:	___ ___ ___ ___ _:	___ ___ ___ ___ __:
Area (ha)		:	___ ___ ___:	___ ___ ___ _:	___ ___ ___ _:
Crop/Variety		:	___ ___ __:	___ ___ ___:	___ ___ ___:
Date		:	__ ___ ___ ___:	___ ___ ___ ___ ___:	___ ___ ___ ___ ___ _:
Crop Operation		:	___ ___ __:	___ ___ __:	___ ___ ___:
FAM Operator	(hrs)	:	___ ___ ___:	___ ___ ___ _:	___ ___ ___ __:
Wife	(hrs)	:	___ ___ ___:	___ ___ ___ _:	___ ___ ___ __:
Male adult	(hrs)	:	___ ___ ___:	___ ___ ___ _:	___ ___ ___ __:
LAB Female adult	(hrs)	:	___ ___ ___:	___ ___ ___ _:	___ ___ ___ __:
Child	(hrs)	:	___ ___ ___:	___ ___ ___ _:	___ ___ ___ __:
HIRED LABOR Hired adult male	(hrs)	:	___ ___ __:	___ ___ ___:	___ ___ ___ _ :
Total wage	(Peso)	:	___ ___ ___ ___:	___ ___ ___ ___ _:	___ ___ ___ ___ ___:
Hired adult female	(hrs)	:	___ ___ __:	___ ___ ___:	___ ___ ___ _:
Total wage	(Peso)	:	___ ___ ___ ___:	___ ___ ___ ___ _:	___ ___ ___ ___ __:
Hired child	(hrs)	:	___ ___ __:	___ ___ ___:	___ ___ ___ :
Total wage	(Peso)	:	___ ___ ___ ___:	___ ___ ___ ___ _:	___ ___ ___ ___ __:
EXH Exchanged male	(hrs)	:	___ ___ ___ ___:	___ ___ ___ ___ _:	___ ___ ___ ___ __:
Exchanged female	(hrs)	:	___ ___ ___ ___:	___ ___ ___ ___ _:	___ ___ ___ ___ __:
Food: hired/exch labor	(peso)	:	___ ___ ___ ___:	___ ___ ___ ___ _:	___ ___ ___ ___ __:
Power/machine/implement code		:	___ ___ :	___ ___ :	___ ___:
Power/machine/implement cost		:	__ ___ ___ ___:	___ ___ ___ ___ ___:	___ ___ ___ ___ ___ _:
Material kind		:	___ ___ __:	___ ___ ___:	___ ___ ___ __:
Material quantity	(kg/li)	:	__ ___ ___ ___:	___ ___ ___ ___ ___:	___ ___ ___ ___ ___ _:
Material Unit		:	___ :	___ :	___:
Material value	(peso)				

Field Aide _____ Remarks : _ _ _ _ _ _ _ _ _ _:_ _ _ _ _ _ _ _ _ _ _ _ _ _ : _ _ _ _ _ _ _ _ _ _ _:

Appendix Table 2. Sample income and expenses data, Philippines.

FN	DATE	TRADE	VALUE	QTY	SURS
11	080187	0271	10.00	0.45	2
11	080187	0361	3.00	0.00	1
11	080187	0111	9.00	0.00	1
11	080187	0111	13.00	0.00	6
11	080187	0061	5.00	0.00	5
11	080187	0222	5.00	0.74	3
11	080187	0352	1.50	0.00	3
11	080187	B141	200.00	0.00	0
11	080187	A021	150.00	42.00	5
11	030187	B132	27.00	0.00	5
12	061387	0212	98.00	15.75	3
12	061387	0262	20.00	1.25	2
12	061387	0271	10.00	0.50	2
12	061387	0111	5.50	0.00	5
12	051387	0371	10.25	0.00	5
12	061387	0391	2.00	0.00	2
12	061387	0352	4.50	0.00	4
12	061387	0222	2.50	0.37	3
12	061387	0041	9.00	0.00	5
12	061387	0252	30.00	1.00	3
12	062087	3212	135.50	21.75	3
12	062087	0261	20.00	1.00	1
12	062087	0371	6.75	0.00	1
12	062087	0371	3.50	0.00	5
12	062087	0311	15.00	0.00	1
12	062087	0141	18.00	0.00	0
12	062087	0121	4.00	0.00	0
12	062087	0041	5.03	0.00	1
12	062087	0351	1.00	0.00	4
12	062087	3232	6.00	4.00	3
12	062087	4161	30.00	0.00	3
12	062787	D212	130.90	21.00	3
12	062787	D041	11.50	0.00	1
12	062787	D371	13.75	0.00	1
12	062787	0311	23.00	0.00	1
12	062787	C211	25.00	0.00	1
12	062787	0251	10.00	0.33	1
12	062787	0261	15.00	0.75	1
12	062787	0121	10.00	0.00	0
12	062787	0352	1.00	0.00	4
12	062787	0222	0.00	0.37	3
12	062787	A051	144.00	20.25	3
12	062787	B132	100.00	0.00	2
12	070487	0212	130.90	21.00	3
12	070487	0261	23.00	1.10	1
12	070487	0311	7.50	0.00	1
12	070487	0371	7.00	0.00	1
12	070487	0361	4.00	0.00	1
12	070487	0211	65.00	0.00	1
12	070487	0061	14.00	0.00	1
12	070487	0121	4.00	0.00	0
12	070487	0352	2.50	0.00	4
12	070487	0222	7.00	0.74	3
12	070487	0411	5.00	0.00	0

Appendix Table 2. Sample crop production data. Philippines.

113211.0201011987095 1	5.0	0.0	1.0	0.0	0.0	1.5	20	0.0	0	0.0	0	0.5	0.0	10	0	0	0	0.00	0
113221.02010119870905111	10.0	2.0	2.5	0.0	1.0	1.0	15	0.5	10	0.0	0	2.0	1.5	20	0	0	0	0.00	0
l13221.02010119870912 13	8.0	0.0	7.0	0.0	0.0	2.0	35	0.0	0	0.0	0	4.0	0.0	25	0	150	0	0.00	0
113221.02010119870926111	4.0	2.5	1.0	0.0	1.5	2.0	35	7.0	35	0.0	0	4.0	2.0	35	0	0	0	0.00	0
222311.00010119870307 5	10.0	2.7	3.5	0.0	0.5	0.0	0	0.0	0	0.0	0	2.0	1.5	34	0	0	0	0.00	0
311113.00011119870314112	5.0	3.0	2.5	0.0	0.5	1.2	45	3.0	45	0.0	0	10.0	8.0	50	3	300	0	0.00	0
422132.50010919870321111	5.5	3.5	6.0	0.0	1.5	0.5	35	0.5	35	0.0	0	4.0	2.5	25	0	0	0	0.00	0
521121.50011919870328115	9.0	3.5	5.2	0.0	1.0	4.0	50	3.0	50	0.0	0	4.0	2.0	25	30	150	0	0.00	0
611221.50011119870307 5	6.0	8.0	4.0	0.0	1.5	0.0	0	0.0	0	0.0	0	6.0	3.0	35	0	0	0	0.00	0
721331.80019919870926155	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	0.0	0	8	700	10	250.09	100
811112.00010919870919154	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	0.0	0	6	300	0	0.00	0
911113.00011119870912155	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	0.0	0	9	450	7	385001	450
022212.30010919870905155	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	0.0	0	19	1000	7	450.04	300
113221.02010119870905 1	5.0	0.0	1.0	0.0	0.0	1.5	20	0.0	0	0.0	0	0.5	0.0	10	0	0	0	0.00	0
113221.02010119870905111	10.0	2.0	2.5	0.0	1.0	1.0	15	0.5	10	0.0	0	2.0	1.5	20	0	0	0	0.00	0
113221.02010119870912 13	8.0	0.0	7.0	0.0	0.0	2.0	35	0.0	0	0.0	0	4.0	0.0	25	0	150	0	0.00	0
113221.02010119870926111	4.0	2.5	1.0	0.0	1.5	2.0	35	7.0	35	0.0	0	4.0	2.0	35	0	0	0	0.00	0
222311.00010119870307 5	10.0	2.7	3.5	0.0	0.5	0.0	0	0.0	0	0.0	0	2.0	1.5	34	0	0	0	0.00	0
311113.00011119870314112	5.0	3.0	2.5	0.0	0.5	1.2	45	3.0	45	0.0	0	10.0	8.0	50	3	300	0	0.00	0
422132.50010919870321111	5.5	3.5	6.0	0.0	1.5	0.5	35	0.5	35	0.0	0	4.0	2.5	25	0	0	0	0.00	0
521121.50011819870328115	9.0	3.5	5.2	0.0	1.0	4.0	50	3.0	50	0.0	0	4.0	2.0	25	30	150	0	0.00	0
611221.50011119870307 5	6.0	8.0	4.0	0.0	1.5	0.0	0	0.0	0	0.0	0	6.0	3.0	35	0	0	0	0.00	0
721331.90019919870926155	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	0.0	0	8	700	10	250.09	100
811112.00010919870919154	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	0.0	0	6	300	0	0.00	0
911113.00011119870912155	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	0.0	0	9	450	7	385001	450
022212.30010919870905155	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	0.0	0	19	1000	7	450.04	300
113221.02010119870905 1	5.0	0.0	1.0	0.0	0.0	1.5	20	0.0	0	0.0	0	0.5	0.0	10	0	0	0	0.00	0
113221.02010119870905111	10.0	2.0	2.5	0.0	1.0	1.0	15	0.5	10	0.0	0	2.0	1.5	20	0	0	0	0.00	0
113221.02010119870912 13	8.0	0.0	7.0	0.0	0.0	2.0	35	0.0	0	0.0	0	4.0	0.0	25	0	150	7	0.00	0
113221.02010119870926111	4.0	2.5	1.0	0.0	1.5	2.0	35	7.0	35	0.0	0	4.0	2.0	35	0	0	0	0.00	0
222311.00010119870307 5	10.0	2.7	3.5	0.0	0.5	0.0	0	0.0	0	0.0	0	2.0	1.5	34	0	0	0	0.00	0
311113.00011119870314112	5.0	3.0	2.5	0.0	0.5	1.2	45	3.0	45	0.0	0	10.0	8.0	50	3	300	0	0.00	0
422132.50010919870321111	5.5	3.5	6.0	0.0	1.5	0.5	35	0.5	35	0.0	0	4.0	2.5	25	0	0	0	0.00	0
521121.50011819870328115	9.0	3.5	5.2	0.0	1.0	4.0	50	3.0	50	0.0	0	4.0	2.0	25	30	150	0	0.00	0
611221.50011119870307 5	6.0	8.0	4.0	0.0	1.5	0.0	0	0.0	0	0.0	0	6.0	3.0	35	0	0	0	0.00	0
721331.80019919870926155	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	0.0	0	8	700	10	250.09	100
811112.00010919870919154	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	0.0	0	6	300	0	0.00	0
911113.00011119870912155	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	0.0	0	9	450	7	385001	450
022212.30010919870905155	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	0.0	0	19	1000	7	450.04	300

FSR AND THE DANGLING /E: EXTENSION, INFORMATION FLOW AND THE FARMING SYSTEMS APPROACH IN NIGER

Frederick Sowers and Ousseini Kabo[1]

INTRODUCTION

FSR's diffuse geographic, disciplinary and institutional genesis spawned a repetition in process that has solidified its edifice but done little to ensure political well being. Moreover, with so many nascent efforts to apply its concepts and methods and to relate them in a scientifically defensible manner, the raison d'etre of FSR — delivering new technologies to the intended farming clientele — has often been subverted to a more limited employ, as a tool of agricultural research. Beyond this core of scientific research that rightfully directs our attention toward the real-world parameters of technological change lies the more difficult mission of bringing about that change. This paper attempts to make a modest contribution in this latter sense.

The objective is to contribute to the growing recognition that in making the farming systems approach work, extension, the "dangling /E," must transcend its junior partner role relative to research (Cernea et al., 1985). The basic tenets of FSR have been with us for some time and will undoubtedly reappear in any reformulation of the technology transfer dilemma; the challenge is thus one of capitalizing on the heuristic advances of FSR before institutional commitment to the approach withers. One relatively neglected avenue lies in inviting extension to the party. To date, the nature, the manner and the conceptual frameworks within which to accomplish this task remain insufficiently developed. To capture the sense of this endeavor we propose to add yet another semantic twist to the lexicon of farming systems. We will argue for what we term Extension with a Farming Systems Perspective, or E/FSP. The ideas and content of E/FSP are not entirely novel. It is rather the emphasis and acknowledgment of the importance and need to expand extension's role that is new.

This presentation is divided into two major sections. The first considers some common tendencies of agricultural research, including FSR/E, that leave extension comparatively isolated. We then develop the salient characteristics and key assumptions of E/FSP. The first section concludes that extension can and should play a vital role in a national communications and information management system directed to improving the technological options made available to small farmers. The second section describes how this vision of extension is being crafted into a strategy of change in Niger, endeavoring to show how E/FSP guides the actions and propositions of an Extension Planning and Management Unit within the Niger Ministry of Agriculture and Environment. The underlying theme is one of improved communication and information flow.

[1]Ousseini Kabo is with the Ministry of Agriculture, Niamey, Niger.

RESEARCH BIAS

Research, including FSR, is often tempered by the directives of the institutions from which it evolves. Frequently, the institution responsible for implementing FSR is mandated to work with a single or limited number of crops. Farming systems research is more complex and comparatively neglected by both the International Agricultural Research Centers (IARCs) and the national agronomic research systems (NARS). National research structures often inherit and retain an on-station research bias. Reduced exposure to what happens off-station tends to shift blame, often wrongly, to extension when technologies are not adopted. Under this research-dominated paradigm, there is little motivation for extension to take the lead in changing the approach.

In addition, research's linkage to extension suffers from the "ivory tower syndrome." Research scientists are often better trained, better paid and better supported than their extension counterparts. Professional networking is research oriented, which contributes to a poorly defined and ineffective research-extension liaison. FSR's role in bridging the research-extension dichotomy too often remains theoretical, and classical isolation prevails:

> Historically, research has stopped too early in what should be a continuous and dynamic process of development and diffusion of new technology. Researchers have been physically and mentally isolated from farmers and have handed down an unfinished, untested product to extension staff. Extension contact staff — squeezed between farmers they live among, who often ridicule the technologies they bring and their superiors, who demand results — have been caught in a crisis of morale (Collinson, 1985).

EXTENSION SYSTEMS AND FARMING SYSTEMS

Extension workers, by the nature of their task, are compelled to work with whole farming systems. Their contribution to the Success of technology adoption should be substantial. Why, then, has the extension not kept pace with parallel FSR initiatives in research?

There are a host of factors that frequently hinder extension activities. Information is sometimes slow in filtering to the extension workers, and by the time it arrives, farmers may already have been informed. Extension workers are often poorly or inappropriately trained; career advancement possibilities are limited; field agents receive minimal logistical and budgetary support; the credit and input supply systems required by new technologies are often inadequate; field personnel frequently have a multitude of nonextension tasks; to summarize in the words of the World Bank, extension systems are "complex and problem prone."

FSR/E complements classic commodity and subject matter research problems. As a comprehensive and systematic approach, it proposes to

maintain solid and dynamic relations between research and extension. With few exceptions, however, FSR/E programs demonstrate only minimal involvement in extension. Extension's role has been confined to supporting research:

- helping identify farmer needs and specifying technologies to test
- aiding in the collection of survey data
- participating in the selection of farmers to carry out on-farm trials
- monitoring on-farm trials
- organizing "open door" or other structured visits to ongoing trials

The FSR/E approach has not used extension workers to disseminate and diffuse "proven" farm-tested technologies. After on-farm testing has refined on-station research, a "research recommendation" is passed in traditional fashion to extension for dissemination. (This implies that extension will carry out a passive transmission function in catalyzing the innovation diffusion process.) In practice this has rarely worked, and it may now be time to rethink the extension process, at least in many contexts.

The key element lacking in most (including Niger's) extension programs is feedback. With some effort on extension's part, this limitation can be overcome, and a systems approach could be used to disseminate technology. This requires extension to perform diagnostic and monitoring functions where the focus is technology diffusion rather than technology generation. In contrast to the multidisciplinary diagnostic and design teams of FSR, diagnostic and monitoring functions would be carried out by extension workers on an ongoing basis throughout the geographic unit covered by the given extension organization. Extension workers would play a central role for their service region. They would be supported by technical staff from the agricultural production and research services. These professionals would have primary responsibility for ensuring that the information on technology adoption and modification is fed back into the technology generation and transfer process. These functions can be instituted or reinforced without major institutional reorganization, improving information management within already existing structures. Figure 1 offers a simple model of information flow in a research-extension system where extension uses, farming systems perspective.

EXTENSION WITH A FARMING SYSTEMS PERSPECTIVE, E/FSP

The following study identifies some assumptions and general characteristics of E/FSP.

- The promotion of new technology, while remaining the fundamental task of extension, discards its tendency to tell the farmer what to do. Instead, an integrated process that begins with identifying farmer problems leads to the promotion of technical solutions as <u>options</u> and continues, with an eye toward modification and refinement, through the adoption of the option. This concern with integration and confirmation of new technology and communication of such information represents the core of the change in the extension paradigm.

- Involving agents in farmer experimentation could contribute substantially to understanding and facilitating the technology adoption processes at the local level. Substantial flexibility and skill in communication are required to develop and maintain the close relations implied by this coexperimental attitude.

- The methods of farmer-level validation and adaptation of technology may be those of local ethnoscience or may be tied to traditional extension trials and demonstrations. The extension agent is a source of new ideas and options that are tried if they are sufficiently interesting to the farmer.

- The tools of evaluation will follow and provide structure to those of the farmer, but extension must aggregate and analyze the data. The real-world context of E/FSP dictates an expanded role for the social sciences in contrast to the usual preoccupation with economic surveys. Those economic considerations that are more important to the farmer than to the economist would naturally enter the analysis, albeit with minimal quantitative rigor.

- E/FSP thus conceived does not replace but complements FSR as a research tool. It eschews top-down concepts in the form of "research recommendations" that are assembled into "technical packages" to be passed on to the "typical or average farmer." As with other steps in the systems approach, feedback plays an important role, but the scale is more encompassing. Instead of a handful of farmers, thousands may be involved.

WHERE NEXT

If the FSR/E methodology is to realize its potential as a blueprint for small farm development, the pernicious problems of managing and structuring institutional linkages, communication processes and the flow of information will become as important as the technical constraints that have dominated the agenda. As the analysis above indicates, extension is within this information generation and communication system. E/FSP begins where FSR usually leaves off; it gives form to FSR's dangling /E.

A conclusion to this first section is that each particular historical and institutional situation must be analyzed (diagnosed) and the results of this inquiry should form the basis for the testing of solutions. One of the strengths of the farming systems approach is its situation specific versatility. The Niger case presented below illustrates how the interplay between general and specific, between theory and practice, can be fashioned, as indeed it must be so as to transform the flow of information without negating the past structures of research and development.

THE NIGERIEN CASE

Niger's 6 million people survive under some of the most trying agronomic conditions imaginable. (That more than 80% of the population are

principally farmers or herders is a testament to their knowledge and determination in exploiting the environment's limited potential.) The Sahara Desert encompasses more than three-quarters of the country's 1,267,000 km^2 (Map 1). The remaining band of sahelian steppe and savanna is dominated by relatively infertile sandy soils. With only a small portion of the country above the 600 mm isohyet, inter- and intra-season variability further compound the challenges facing rainfed agriculture. Drought, monetary pressures and population growth have combined to undermine the stability of the fallow based cropping systems in which millet, sorghum and cowpeas remain dominant. A readily adoptable formula for increasing production is not evident. Research recommends an almost unvarying technical package for the entire country. The "package" has come under increasing scrutiny by the national research institute (Ly et al., 1986) after having been actively promoted with little success for almost 15 years. (Republique du Niger, 1985).

To facilitate the development of more responsive research, extension and production support programs within Niger, the National Cereals Program was established and funded by USAID in the early 1980s. Recommendations from the research and production support components began to accrue by the mid-1980s. The Extension Support Center (ESC) has just completed its first year of operations. Most of the year was devoted to diagnosing and analyzing the strengths and weaknesses of the extension system and its relationship with the National Institute of Agricultural Research (INRAN). The information base developed provides our point of departure.

The National Cereals Program provides a unique base from which to improve communication and information management with the research-extension system. It is primarily an institution-building program in which the two principal beneficiaries, research and extension, are separate institutions. Only since 1984 have they coexisted within the same ministry. The cereals program has a coordinating unit designed to harmonize the action of two support projects, one for research and the other for production, including extension, seed multiplication, input supply and cooperative development. However, neither the coordinating component nor the "liaison units" that appear in both extension and research's organizational charts have succeeded in bridging the two.

As is evident from Fig. 2, communication between the two institutions must pass vertically up and down the respective hierarchies. This inhibits collaboration in the field and reduces the flow of information. The institutional structures of research and extension do not encourage dialogue. The ESC has concluded that an effective liaison must be defined by interactive processes that follow naturally from routine operations (CAV, 1987). Such liaison is indispensable if an E/FSP program is to develop.

INSTITUTIONAL BACKGROUND: THE GENESIS OF A DILEMMA

Extension's roots in Niger lie within the colonial preoccupation to stimulate Nigerien farmers to produce and market cash crops. Although fledgling institutions such as a rural agent training school and a research station had been founded by the 1930s, substantive action was

minimal until after the worldwide economic slump and World War II. During the post-World War II period, several attempts were made with little success to transfer the improved groundnut varieties and associated cultivation practices developed on French experimental stations in Senegal to Niger.

In the post-Independence period, efforts to intensify production were given a new boost through the rural animation programs carried out in conjunction with development of cooperation credit and marketing institutions. Production increased, but whether from expanded acreage or from the improved package was debated (Raynault, 1975). In the words of one observer, the efficacy of this package "was left to the farmer to discover first and the agronomist to confirm later" (Roberts, 1980).

The 1970s were characterized by two major developments. The first was a shift in emphasis from cash crops to food crops. By the early 1970s, inequitable access to credit and marketing institutions, a collapsing groundnut economy and drought combined to undermine the commodity focused programs. The second important development was the advent of new institutions for agricultural research and extension. For agricultural research, INRAN was created in 1975 by consolidating various French research organizations. Extension was invigorated with a generous injection of capital via the establishment of a series of foreign financed regional "productivity projects." The projects, varying in organization and source of funding, adopted similar formulas for extending the available techniques for increasing production.

The productivity projects in turn established a network of farmer training centers throughout the agricultural zones. Upon returning to their villages, farmer-trainees were given the responsibility of promoting and instructing fellow villagers on the use of the new technologies.

The extension programs met limited success as evidenced by low trainee adoption rates and limited diffusion of the "technical package" (Barnett, 1983). Moreover, new research began to question the effectiveness of certain elements of the package (DECOR, 1984; Hagen et al., 1985). Finally, the fiscal crisis that began in the early 1980s with the collapse of the Nigerien uranium economy challenged the viability of this research-extension system (Painter, 1985; Republique du Niger, 1982).

From 1981 onward, under the shock of an international economic crisis, Nigerien technicians and policy-makers alike sensed a need to refocus rural intervention methods. The productivity projects were judged too cumbersome and expensive relative to their impact on farmer practices. In their place a partnership between permanent government structures and newly created local organizations was proposed. A greater responsibility was to be placed on rural inhabitants through their active involvement in the programming and execution of development programs. The participatory ideology of this new "development society" opened the door to the farming systems approach.

FSR/E IN NIGER

Within INRAN, the Department of Rural Economy (DECOR) has taken the lead in developing and applying a variant of FSR. DECOR first develops on-station trials of numerous technical alternatives of which the more promising are subsequently tested on farms. This OFR program envisages the development of new recommendations. The DECOR program, however, remains centered on developing an optimal technical package. Diagnostic surveys lead to an OFR aimed at testing/modifying the existing package and not redefining the research agenda. This approach represents a step toward the farmer (seen for example in the shift from mono- to inter-cropping research), but it falls short of fully accommodating the parameters of farmer decision making vis-à-vis the adoption and application of new technologies (Byerlee and Polanco, 1986). Nor has the DÉCOR OFR program improved the research/extension liaison. INRAN recruits its own research assistants for both survey work and field trials. Moreover, the communication of progress and results, of potential interest to extension, must pass through an arcane bureaucratic routing before becoming available to extension workers. Field agents, with the notable exception of the Maradi Department, remain only vaguely aware of the DECOR program.

INRAN has been the subject of two recent institutional reviews. Both conclude that the institute should improve its outreach to clients. The first, a joint INRAN-ISNAR review, indicates that INRAN could take better advantage of the basic research carried out in the international centers and focus on applied programs, especially those involving OFR. The second, a background study for the proposed Niger Applied Agricultural Research Project, concurs that an expanded program of on-farm trials is in order and recommends that downstream linkages to extension be reinforced and formalized.

In its first years (1976-1984), the Maradi Department Productivity Project elaborated its program by following a classical top-down communication method, but in 1984, it was restructured similar to the francophone "recherche-développement" strategy. Thus far, a series of diagnostic surveys have been carried out and a farm trials program (in conjunction with DECOR) initiated.

Niger has committed itself to a series of training programs in FSR/E, some sponsored by research, others by extension. Foremost among these efforts was a recent national seminar on FSR/E. It was unique in that it was directed to agricultural extension and production professionals as well as to university and technical school professors. The program was sponsored by the ESC and the Niamey Department Development Project with technical assistance from the Farming Systems Support project. Combined with numerous participants in regional FSSP and CIMMYT FSR/E training programs, a critical mass of trained cadre has been attained that should soon enable significant policy decisions with regard to FSR's institutionalization.

The strides made by DECOR, the Maradi Project and by the ESC's training programs have opened the way to more comprehensive development of FSR/E in Niger and underscore the timeliness of the ESC's institutional analysis of Nigerien extension programs.

INFORMATION AND COMMUNICATION: THE CURRENT STATE OF EXTENSION IN NIGER

Methodology

The ESC's objective follows the government strategy of reinforcing the permanent structures of extension. Because the regional and subregional structures are frequently still operating in the shadow of the productivity projects, the ESC solicited proposals for model extension programs from each department. The implementation of these small-scale programs offered a unique optic through which the philosophy, methodology and operation of the extension services could be observed. A multidisciplinary team (consisting of an agronomist, agricultural economist, geographer, sociologist and regional administrator) was constituted to study and analyze the program as it was being carried out. This sondeo team examined the content of the programs as well as the various interfaces of communication along the research-extension-farmer and national-regional-subregional-village continuums. The initial sondeo has been reinforced by a subsequent program of ongoing analysis.

Research-Extension Liaison

The contacts between research and extension in Niger take place almost exclusively during the separate annual meetings of the institutions. To a lesser degree, interaction takes place in the regional validation trials and during visits to research stations by agents, but for the most part, day-to-day operations are entirely segregated. Internally, extension is characterized by poor communication, lack of effective and cohesive methodologies and inability to disseminate a message beyond the contents of the standard INRAN technical package. Moreover, financial and logistical resources are virtually absent except where buttressed by donor funds.

One of the few areas of contact between research and extension occurs in the regional trials. Research unilaterally elaborates regional trial protocols independent of extension but claims that the protocols are designed to respond to extension's expressed needs. Extension often receives the protocols too late to make adequate plans and to ensure delivery inputs in a timely manner. The result is that trials are often implemented in a crisis management mode with extension staff feeling that the trials have been "parachuted" onto them at the last moment. Researchers seldom visit the trials, and agents conducting them are often inexperienced and inadequately trained. The results are minimally exploited and rarely given to the personnel implementing the trials. Agents who do not fully understand the functions of regional trials are unable to explain them to the farmers. Since farmers do not understand the trials, it is difficult to get them to supply the land and labor essential for the trials. Moreover, many at the highest levels of research and extension consider the trials to be extension demonstrations, not stability or validation tests of technologies. Finally, the trials program has not led to changes in recommended farming practices.

Communication and Information

The lack of a mechanism for transmitting information between hierarchical levels of the extension and related agricultural services gives the overall system a static rigidity that seems to function best in a crisis, e.g., insect attacks or in mounting an emergency dry season gardening program. The lack of information and inability to effectively communicate through existing structures manifests itself in a number of symptoms:

- Scarcity of documentation at all levels; inability to reproduce and distribute existing materials; poorly organized or nonexistent archival retrieval systems.

- The experience and knowledge of extension workers has not reached those in research and policy to make use of the information. No systematic inventory and evaluation of the extension methods used in Niger has been undertaken.

- Field level agents provide little input into the annual agriculture service meetings where plans for the upcoming agricultural campaign are made.

- Important issues are raised and debated at the annual meetings, but the recommendations are insufficiently circulated and seldom implemented.

- National policies and the implementing procedures are imprecise, confuse role definition and repartition technical responsibilities.

- Existing channels of government-farmer communication (i.e., mass media) are underexploited and are not coordinated with other extension efforts.

The flow of information is unilinear up or down hierarchical structures. The agent who sends information up the hierarchy seldom receives feedback. There is no bulletin to facilitate the spread of ideas and information among personnel of different institutions. Reports are not exploited to their fullest potential. Information gathering and dissemination are hindered and complicated by lack of transportation. Rigid bureaucratic channels and procedures often mean that field requests to support specific programs do not receive thorough consideration by those responsible for funding decisions. These same structures inhibit horizontal communication within the ministry. These factors favor the continuation of cumbersome and homogenous programs over locally responsive and dynamic efforts.

Role Definition and Information Flow

Job responsibility attributes are poorly defined. In Niger, the district agent is assigned a multitude of duties from numerous technical branches of the ministry. The agent is the representative of the agricultural statistical service, pest control service and agricultural production service and is a contact person for research. His duties

include collecting statistics, monitoring crop growth and pluviometric conditions, conducting agricultural demonstrations, following up on returned farmer-trainees, conducting INRAN trials, participating in the seed multiplication program and organizing the off-season agricultural campaign. Overloaded schedules are less a problem than confusing role definitions, in adequate training and prioritization of activities.

Districts are several tens of kilometers in length and breadth and comprise on average between 30 and 70 villages. With no government transportation, the district agent conducts a few activities in the neighborhood of his village and has transportation only when representatives from the arrondissement, department or central levels visit his district. Program execution is fragmentary and uneven.

Under such conditions, the agent's initiative is sometimes discouraged, certainly not rewarded. The tendency for agents to become front-line troops in the execution of distantly conceived programs is reinforced. Modification of these programs is forbidden. In consequence, the agent develops little discretion relative to the appropriateness of research recommendations and other interventions. Moreover, agents are not inclined to apprehend and analyze the reasons that local farmers are not adopting new technologies. In many instances, agent-farmer communication is ineffective to the extent that farmers are seen as "reticent" and uncomprehending. As these problems become clear to the agent, his frustration increases.

The agents are isolated. Their involvement in the ministry planning process is minimal, and their insights into the logic of farmer decisions are inhibited. Relations with other technical services are poor or nonexistent. Furthermore, the shift in the rural development paradigm in the early 1980s, which placed greater emphasis on local participation, has not resulted in major changes in the agent's roles. New participatory development organizations, made up of the rural population, correspond with administrative divisions and include people from village to national levels. The agent, who once enjoyed the role of venerated news bearer as he arrived by horse or camel in isolated villages, is not maintaining his/her role with a rural milieu evolving under the influence of the new development organizations, exposure to mass media and frequent travel outside the village. If the agent's role is to be successfully molded into one of partner and counselor, his exposure to information, the capacity to relate knowledge and action and the district agent's place within the overall "grid" of rural development institutions must be treated systematically.

At the departmental level, a group headed by agronomists, rural engineers and statisticians was recently constituted, but at present a clear charter is absent. Exact roles and functional relationships within this group and between the departmental and older levels remain ambiguous. The problems of technology development and transfer in Niger require that the total system be engaged to address the issues outlined. Only in this way can the information generated by E/FSP be sufficiently empowered to contribute to building a successful national FSR/E strategy.

THE EXTENSION SUPPORT CENTER: A BLUEPRINT FOR COLLABORATION

The problems facing Nigerien agricultural institutions have reached a turning point. The willingness to reorient policies and strategies bodes well, considering the stagnation in food production. The new directions taken will manifest themselves incrementally at the research and extension levels. Fortunately, it is not so much the structures of the organizations that demand change; their vitality depends, rather, on an improvement in the volume and quality of interchange within and between them. The ESC strategy is thus founded on advancement in three major areas:

- information
- communication
- training

As a branch of the National Extension Service assigned planning and analysis functions, the ESC is the major contributor to the conception and implementation of extension programs.

In the fall of 1986, after carrying out the institutional sondeo, the proposed ESC strategy and work plan were adopted by the ministry. This marked a major commitment to an uncharted course. The program affects not only the handful of technicians within the ESC but, in varying degrees, engages the entire research-extension establishment. It envisages a system that creates and maintains a permanent process of technology adaptation and diffusion that responds to local needs.

Collaboration between the regional team and the ESC to reorient the activities of the field agents constitutes the core thrust of the strategy. This implies improving the agent-farmer linkage and making the remainder of the extension program more responsive to the information from farmers. Thus, the methodological challenge of the program is to encourage agents to better define farmer problems, to be capable of proposing appropriate solutions, to be responsive to constraints in the adoption process and to participate in the evaluation and modification of proposed technologies and methods of promotion.

The ESC is composed of four closely linked units: training, audiovisual/documentation, methodology and extension-research liaison. The division encourages the pursuit of a single strategy simultaneously along a number of fronts. Because the system is apprehended holistically, it is not necessary to follow the steps of the technology transfer process in chronological sequence. The importance of this methodological point concerning the sequencing of FSR/E activities was emphasized recently at the first annual meeting of the West African Farming Systems Research Network:

> by necessity, flexibility must be allowed for skipping certain stages sometimes, spending longer in some phases at times, and for simultaneously working across several phases at times (there is little doubt that currently the weakest phase is dissemination)...(FSSP, 1986)

The ESC recognizes the importance of an adaptive extension service (E/FSP) to a national FSR/E program even though research has yet to provide improved OFR tested recommendations. To this end, the ESC has undertaken a program consisting of the following principal activities.

One of the activities is to better define problems, clientele and appropriate extension methods through a program of in-service training and application. The training program seeks to help agents redefine their roles relative to the farmer from salesman and teacher to partner and counselor. The training introduces informal survey and diagnostic skills to better define the needs of groups of farmers within the district. The ESC is developing innovative methods for extension workers to involve farmer groups in the implementation of proposed solutions. These "contact structures" are composed of interested and inquisitive farmers selected by their cooperative. The farmer groups with intermittent support from extension determine how the new technology is to be tested.

Improved access to information is necessary if agents are going to be able to transfer technology in a flexible manner. To this end, an extension manual is being developed. The manual provides a range of recommendations to be applied according to key factors (expected prices, soil conditions, rainfall pattern, farmer resource endowment). The manual will evolve and be continually updated as research and extension results become available. The documentation center eschews the repository role in favor of a more active "clearing-house" role. Documents, research reports, farmer training aids and other publications are selectively ordered and screened by the technical staff of the ESC and then diffused by mail or through training programs to the appropriate field personnel. A production-quality audiovisual studio provides the ESC direct access through the national network to an estimated *80%* of the population. Coordinating mass diffusion with specific agent programming will become increasingly important. A research-extension liaison bulletin is also in preparation.

The evaluation of training needs is also seen as an ongoing process leading to pertinent in-service training. These sessions correspond to the level of personnel in the overall research/extension system and the stage of the E/FSP process requiring the most immediate attention. In 1986, for example, a national FSR/E seminar was held for higher-level technical personnel. This workshop indicated a need for a shorter "decision-makers conference," which is proposed for this year.

Attention to the dissemination/adoption phases is also leading to new approaches. These include extension-managed on-farm trials, extension demonstrations that include more than one "correct" solution and solicit farmer feedback and technology trials in cooperative fields where participation is motivated by purely economic interests and where risk and demonstration effects are spread among a large group. Technologies that have not been the subject of previous research recommendations such as soil and water conservation and agroforestry techniques are being integrated and supported by training.

The collection, evaluation and exploitation of feedback represent key components of the ESC approach. This is also an area where precedents are few. Most extension programs are monitored in terms of adoption rates or other factors but rarely with, the aim of systematically modifying the other steps of the technology-generation-and-transfer process. Gathering information from nontraditional trials requires new tools. To date formal and informal surveys carried out by the agent are being relied on in conjunction with the on-farm trials and the more traditional demonstrations. First-year data are just coming in. Mechanisms for evaluating and exploiting this feedback are in the development stage. The proposed uses for this feedback include:

- providing the regional level with information that will lead to better planning

- providing research (through annual meetings, the bulletin, publications and periodic reports) with a real-world sense of their technologies' performances)

- contributing to the creation and evolution of pre-extension centers where technologies that are either insufficiently known to agents or are not adequately field tested can be applied

- improving the extension manual at the ESC level, refining training programs and developing better recommendations and promotional methods

CONCLUSION

The appeal of FSR/E's logic and its systematic approach have attracted considerable hope and support in recent years. We have argued that the slowness with which results have followed is in part due to an overemphasis on research and a relative neglect of extension (..../E). Many technologies, no matter how well adapted and tested, will not be adopted without extension's involvement. This is especially true for higher-risk environments such as that of Niger. The appropriate methods of extension may vary with the situation, but it seems clear that they should be dynamic and consistent with the other stages and levels of the technology-generation-and-transfer process. Viewing extension in this light has led us to propose the broad lines of E/FSP. Extension as a full partner can thus enhance the synergistic qualities of the systems approach.

The success of this approach, at least in Niger, rests on enriching the quality of agent-farmer interaction. The "scientists' attitude" toward FSP must be imparted to the agent. Its internalization is as important as the technical and organizational skills needed for his work. As this is accomplished, the research-extension system in which the agent is the final critical link needs to increasingly support the creative potential for new initiatives originating from the agent-farmer interface. The results of this local fine-tuning at the dissemination/adoption/ integration phases has much to offer and should not be lost, as it typically is, to the earlier stages.

Conferring to extension a lead role could breathe new life into the existing institutional structures, thus filling the vacuum left as Niger's chapter of productivity projects and packages comes to a close.

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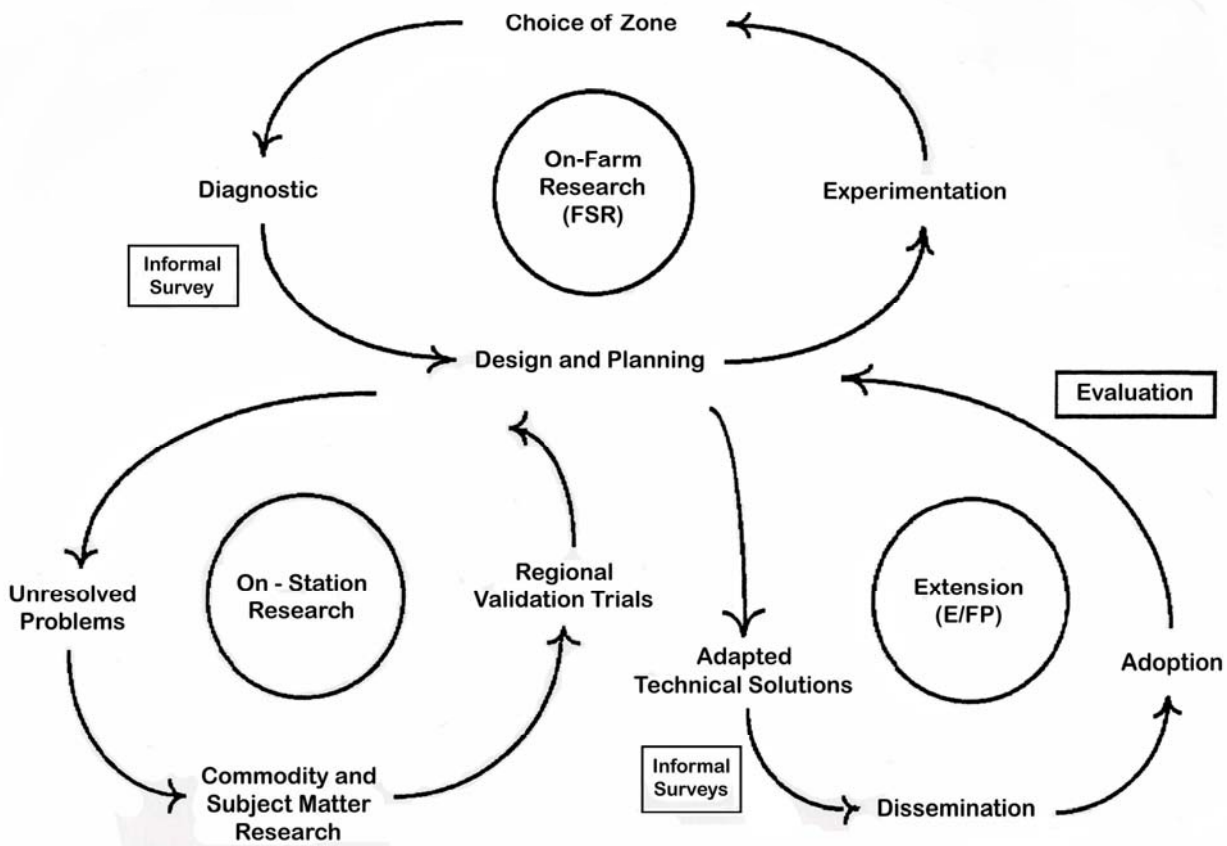
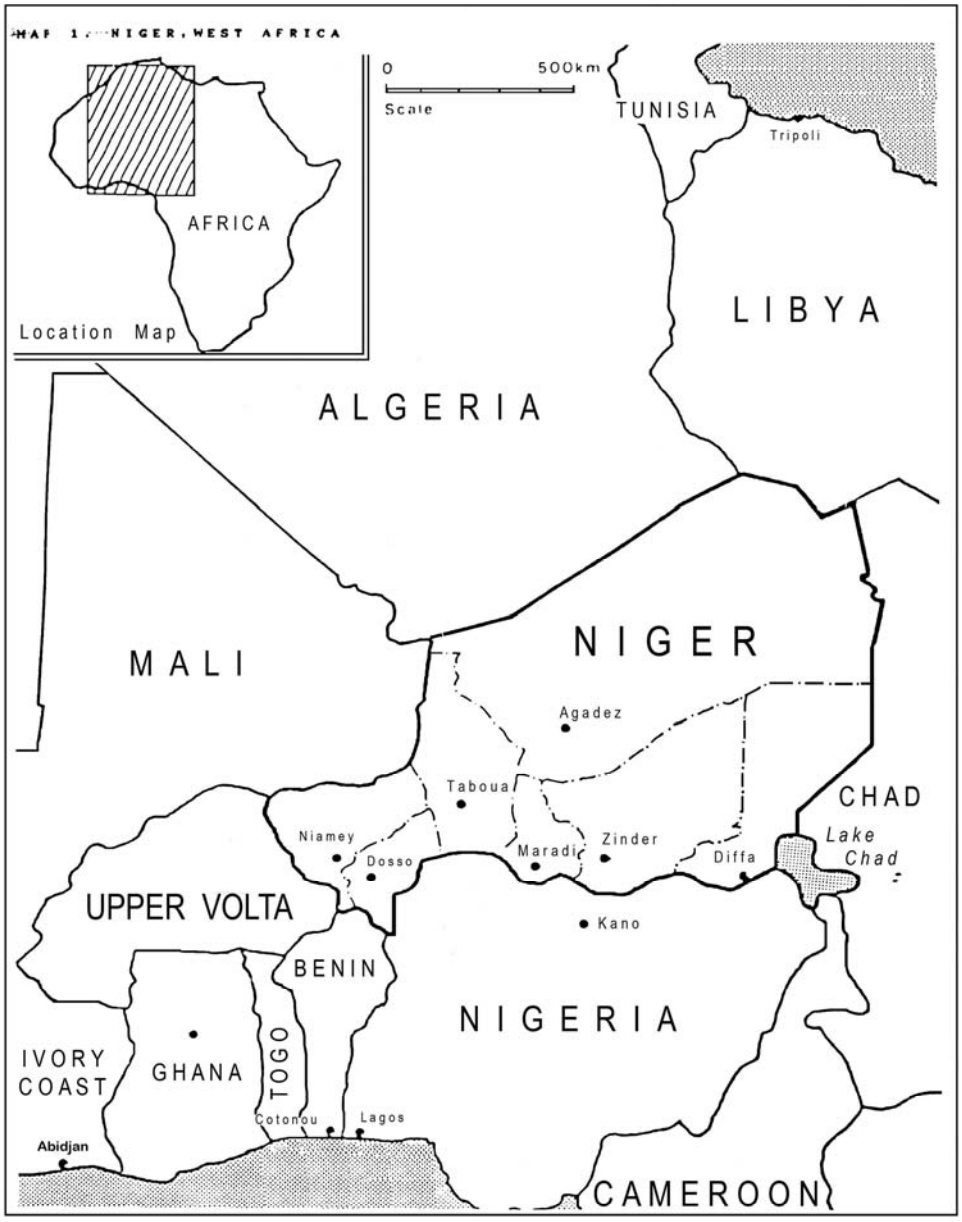


Fig. 1. Relationships between FSR, on-station research and extension.



Map 1. Location of Niger.

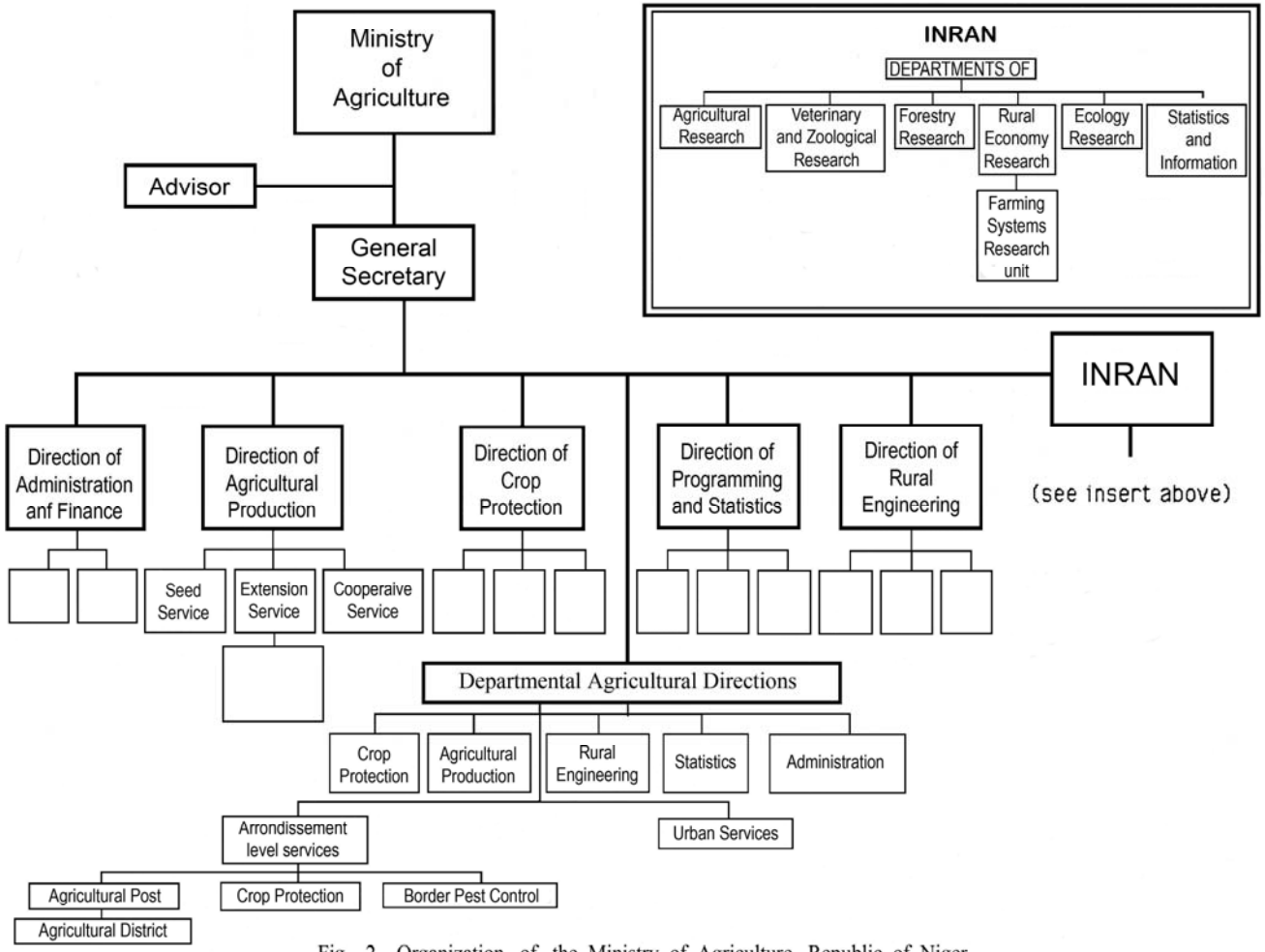


Fig. 2 Organization of the Ministry of Agriculture, Republic of Niger

Macro
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FACTORS AFFECTING THE STABILITY OF SHIFTING CULTIVATION

Fredrick Abeyratne and Daniel B. Taylor[1]

INTRODUCTION

Shifting cultivation is a system of farming widely practiced in Sri Lanka. As defined by Ruthenburg (1971), it is a system in which several years of cropping are followed by several fallow years and in which each year two-thirds or more of the potential cropland is left fallow.

Its successful sustenance depends on maintaining soil fertility and keeping weeds under control. Hence the key factor is the fallow period allowed between rotations. Under this system the availability of land is the constraining factor. Over the years, with population pressure on the land, the length of fallow has been shortened. This has resulted in a drop in productivity and indiscriminate clearing of forests, which has become a national concern.

A BRIEF HISTORY OF SHIFTING CULTIVATION IN SRI LANKA

Shifting cultivation, or "chena" farming in the local dialect, has been in existence in Sri Lanka for centuries and is still practiced at various intensities. In the past, it was a form of agriculture that met the subsistence needs of farming families. Chena farming as practiced in ancient Sri Lanka was only one component of a system including several land types that were under cultivation. Farmers depended on all types of land for their subsistence needs (Abeyratne, 1956). The forest was owned by the village, and clearing of forest land took place by mutual consent.

Since the pressure on the land was minimal, ample time for the fallow period (which is about 8 to 16 years according to Ruthenburg (1971)), was allowed for regeneration of the forests. Therefore, questions relating to the maintenance of fertility, weed control, environmental effects, etc., were of little concern. While population pressure was building in the traditional areas where chena cultivation had been practiced (dry zone), the state began moving people in the 1930s from the heavily populated wetter parts of the country to the dry zone. This resettlement process naturally increased the pressure on the land. This situation was further exacerbated by food shortages and foreign exchange limitations in the 1960s and 1970s. The government embarked on food-production drives during this period, and most of the food crops were grown in the uplands under chena cultivation.

[1]Research Assistant and Assistant Professor in the Department of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg, VA, U.S.A.

Taking advantage of the situation, many businessmen exploited the land in the dry zone by stripping vast areas of forest land for agricultural production and then abandoning them without any attempt to regenerate the forests. All these processes contributed to the destruction of a vital natural resource, the forests. This resulted in the formation of "waste land" (Jochim and Kandiah, 1948), detrimental effects to the ecosystem (Brohier, 1975), timber shortages and threats to wildlife (Guneratne et al., 1980). Although under these circumstances one may tend to dismiss chena farming as a wasteful type of agriculture (Yalman, 1967), when it was practiced in the proper manner with long enough fallow periods, it was in harmony with the ecosystem.

This system of farming has been undergoing a transformation over the years. In fact, from this shifting system of cultivation, a semistable form of upland farming has been evolving. Very little information is available about chena farming practices and the process by which they have been transformed for settled cultivation. Hence it is important to understand this farming practice in order to identify the important factors that are required for a sustainable agricultural system.

At present there are government regulations prohibiting forest clearing for chena cultivation. Farmers are allowed, however, to clear shrub lands (where shrubs are less than 5.5 m tall). The farmers are limited to 0.8 ha per household and must obtain permits to clear shrub land from the government agent of the district before the commencement of the growing season.

PROCEDURES

A study was conducted during the 1982/1983 maha season in four locations in Sri Lanka with different farming systems where chena is an important component. The chena systems studied varied in length of fallow periods and cropping patterns. The objectives of the study were as follows:

- to understand the role of shifting cultivation in the context of the farming system

- to study shifting systems in a dynamic sense considering their transformation in terms of the length of their fallow periods and the dependence of the whole farming system on the shifting-cultivation component

- to assess the effects on the chena method of changes in external and internal conditions such as population increase, marketing, credit, transport facilities, national commodity pricing and land tenure policies

- to identify factors important for encouraging a sustainable form of settled upland agriculture

The field study was conducted by a team of researchers: an agricultural economist, an agronomist and a geographer/sociologist. Although strict farming systems methodology entails quick problem identification and

establishment of on-farm trials to solve priority problems, this paper reports only on the problem identification and makes suggestions for further research. Due to the complex nature of the farming systems studied, more time was spent in problem identification than is usually the case in farming-systems-research programs.

Data were collected from four study locations in the southeast part of Sri Lanka where shifting cultivation is practiced extensively (Fig. 1 and 2). Briefly, the study locations had the following characteristics.

In Kahambana, in the Moneragala District, shifting cultivation is practiced, with long fallow periods and no irrigated farming. Hence the farmers are totally dependent upon shifting cultivation, which is mostly subsistence oriented.

The location in Mahakalugolla, also in the Moneragala District, is characterized by no irrigated farming and total dependence on upland cultivation; fallows are almost nonexistent.

In Badagiriya, in the Hambantota District, farmers practice irrigated rice cultivation as well as shifting cultivation with short fallow periods, depending on both for subsistence. However, they depend more heavily on irrigated agriculture because they have a reliable water source.

In Gonnoruwa, also in the Hambantota District, both shifting and irrigated rice cultivation are practiced. Because irrigation is not assured, the farmers depend primarily on shifting cultivation. The length of the fallow period is longer than that of Badagiriya.

Two types of surveys were conducted for data collection. A large group was interviewed once in order to collect information on broad socioeconomic factors. The details of this sampling are presented in Table 1. Then for each location, a subsample, consisting of 20 randomly selected households from the large sample, was interviewed. The interviews were conducted twice a week for a full cultivation year to collect information on farm household practices. The information in Tables 1 through 7 refers to the large samples.

RESULTS AND DISCUSSION

Shifting Cultivation in the Context of the Total Farming System

Dependence and future prospects. When chena is concurrently practiced with rice farming, the extent of land under chena cultivation depends on the availability of water for rice cultivation. Although both Gonnoruwa and Badagiriya have irrigation water for rice cultivation, only Badagiriya has a reliable source. The less reliable the water supply for rice cultivation, the greater the amount of land under chena (Table 2).

By increasing the amount of land per household under chena cultivation, the farmer appears to reduce risk as the availability of water for irrigation declines.

With the fallow period diminishing, people do not move as frequently. More permanent types of housing were observed on lands having very short fallow periods.

Although chena played a major role in the village economy at the time of the survey, there are negative perceptions about its future. Even though farmers preferred to continue chena cultivation as they have been practicing it, the majority felt that the prospect for doing so was bleak for a number of reasons (Table 3), reasons that varied according to the circumstances the farmers were facing at the time of the study. For example, although diminishing forest area was the most common reason for their pessimism, loss of fertility, difficulty in controlling weeds and laws against forest clearing for chena cultivation were also important. Not surprisingly, in Mahakalugolla, which was the most accessible location, law enforcement was high and was the major reason cited (57% of the responses). This demonstrates the role that outside pressure in the form of legal rulings can play in future development.

Population pressure was felt in Badagiriya and Gonnoruwa, but not in Kahambana, probably due to its location. In Kahambana, lack of forest land was reported to be the biggest constraint (55.5% of the responses). Paradoxically, this response was despite the fact that the availability of forest land there was the highest compared to the other locations. In Kahambana, chena cultivation was practiced with long fallows (Table 2), and, over the years, farmers have had to go into thick jungle because cultivation of preferred nearby land has caused weed problems. In fact, 31.8% of the respondents in Kahambana thought that chena farming was not possible in the future because of weed problems.

Labor use. The availability of farm labor and its pattern of use is one of the most important factors that determines the operation of a particular farming system. Labor allocation is usually decided by the head of the household, depending on the relative productivity of the different components of the farming system. This allocation decision becomes more complex when farmers are unable to obtain institutional credit, limiting their capacity to hire labor.

Labor use in farming depends upon gender. With chena farming, activities such as clearing forest land, burning felled trees, building fences around the chena farm and protecting the chena crop from wild animals during the night are generally performed by adult males. Adult females generally plant, weed and harvest. Children also help with weeding and harvesting the crop. Heavy duties, such as land preparation and threshing, are the man's responsibility, while planting/sowing, weeding and harvesting are the woman's responsibility. The other household activities, including cooking, looking after small children and processing farm products for household consumption, are performed by women.

Some important features of the pattern of labor use in the different farming systems are highlighted here. The largest labor requirements are in irrigation systems, reflecting the use of labor-intensive techniques required for rice cultivation (Tables 4a and 4b). The least use of labor was for Mahakalugolla, the system that did not have a rice component and had very short fallows. Forest clearing, which requires considerable labor, was not required with this short-fallow system because little time was allowed for a thick forest regrowth. The implication of this pattern of labor use is that in situations where labor is scarce or where there is a rising wage-labor market, the potential for settled cultivation is greater. In Mahakalugolla, labor requirements are further reduced by the use of tractors for land preparation. Mechanization is possible because there are no tree stumps (which are common in chenas with long fallows).

In mixed systems (chena and irrigated rice), where dependence is higher on the rice component, mechanization is common (Badagiriya), and there is a relatively higher use of labor in the chena component.

The distribution of labor for different components of the system gives an indication of trends in the labor-use pattern. Here timing and type of labor are particularly important because certain operations are time specific and have to be performed on different types of land within the system. Thus labor competition among chena and rice farming is inevitable, and its nature depends on the priorities set by each farmer.

In locations where chena was practiced with long fallows (Kahambana), there was no labor competition because almost all the efforts were concentrated on the chena. However, when both paddy and chena were in the system, especially when water for irrigation was not reliable, farmers were more dependent on the chena than were farmers with irrigation. Thus they had bigger chena plots than paddy, 4.28 ha acres of chena compared with 0.6 ha of paddy in Gonnoruwa. With the onset of the rains, farmers concentrated their efforts on the chenas first in order to make maximum use of the rainfall. In other words, when two subsystems competed for the same resource (labor), farmers first concentrated on the subsystem from which they were more assured of getting an output.

Crop husbandry and agrotechnology. As shown in Table 5, Badagiriya and Mahakalugolla generally have shorter fallows than do the other two locations. The type of crop husbandry practiced is closely related to the length of fallow. Unlike in the past, when chena farming was purely for subsistence needs, a trend towards commercialized farming was observed at the time of the study. For example, in Mahakalugolla where the fallows are very short, nontraditional crops such as sugarcane are mainly grown as a cash crop. In Kahambana, with long fallows, food crops are grown for consumption as well as for sale.

The change in the cropping pattern over the years demonstrates that farmers are becoming more and more market oriented: they drop certain crops when markets are not assured. For example, in farming systems that completely depend on the chenas, such as Mahakalugolla, farmers produce crops such as peanuts, soybeans and chilies for which they have

a ready market. With the reduction of fallow periods, farmers begin to produce semiperennial crops such as sugarcane and bananas, as well as perennials such as citrus and mangos, growing these near their permanent homes. However, with paddy-chena systems, cropping patterns in the chenas have not changed much, probably because the paddy provides the cash crop and chena production meets subsistence needs. Hence crops such as millet and cassava remain in these chena systems.

Input and output parameters are good indicators of the viability of a particular farming system under a changing environment. Traditionally, chena farming was comprised of minimum-tillage practices after the large trees were cut, burned and cleared (but the stumps were left). However, with the reduction in the fallow period in places such as Mahakalugolla, even tractor tillage was practiced at the time of the study. In Kahambana, with long fallows and minimum tillage, the traditional mixed cropping was giving way to a separate plot for each crop. This change was mainly due to the introduction of cash crops. As described earlier, with long fallow conditions, soil fertility was maintained naturally (requiring no outside inputs). With fallow periods being shortened, outside inputs become a necessity. In Kahambana, with long fallows, no other inputs besides labor have been used for production. Even the seeds for the next year's planting were from the preceding year's production. In Mahakalugolla, with very short or no fallows, there were distinct differences. Rice was cultivated under nonirrigated conditions, but in order to make maximum use of rainwater, bunds were erected around the fields to minimize runoff losses. Improved varieties of rice were cultivated, and certain amounts of fertilizer and other chemicals have also been used, though not to their optimum levels. However, for nonpaddy crops, technology has hardly changed, and outside inputs have played almost no part.

So although fallow periods are shorter, the increase in input use on chenas has been marginal, implying that they have not sustained their productivity. Hence it appears that although chena cultivation has to a certain extent become more stable and settled, the traditional cultural practices used are a serious impediment to productivity. The extensive input use in rice cultivation can be attributed to well-organized extension services provided to the paddy sector and to the availability of institutional credit. Farmers practicing chena cultivation do not have access to institutional loans because such cultivation takes place on illegally cleared forest land rather than on legally owned land.

There were big differences among outputs depending on the length of the fallow period. For example in Mahakalugolla, with very short fallows, the yield of maize was 1,477 kg/ha. In Kahambana, with long fallows, the yield was 2,303 kg/ha. The rice yields in Mahakalugolla were very low at 533 kg/ha when compared to locations with access to irrigation water. For example, Badagiriya had yields of 4,451 kg/ha. As was indicated earlier, the availability of marketing facilities is one of the most important considerations for the selection of crops. Therefore, when markets are assured, farmers tend to grow the crops for which there is a market, even if the productivity is low. In Kahambana, 65% of the chena produce was consumed at home while 60% at Mahakalugolla was marketed. The sales at Mahakalugolla were possible mostly because

conditions were good, making markets more accessible than they were to Kahambana.

Key Factors Influencing Change

The preceding section discussed the performances of different farming systems and the role played by the chena component within each system, subject to the criteria of dependency (for food and sales) and length of fallow. This section identifies circumstances that might impel an individual household or a community to move from one system to another (e.g., shifting from subsistence-oriented chena to semipermanent upland cropping associated with market sales). This information is intended to aid in identifying intervention or leverage points for further research. They are as follows:

Availability of land tenure rights and size of holding. Availability of forest land was the key factor in whether chena was practiced. Yet with the availability of forest land decreasing, farmers were compelled to establish stabilized (semisettled) upland farms. Institutional credit and other official assistance cannot be obtained without land rights. However, since most of the food is produced under the chena system, more than 2 acres of land is required for households to maintain their economic viability. This is a strong argument for changing the land policy from the current permit system that allows only 2 legal acres per household to one under which more upland farmers would have the legal status necessary to obtain institutional loans.

Agroforestry. The combined use of agroforestry and new tillage techniques appears to be crucial in the development of stabilized farming systems in the tropics because they represent an evolution of the age-old forest-fallow system. It is hoped that the research carried out by Handawela at the Maha Illuppallama research station (personal communication, 1984) on simulated forest or avenue cropping (sometimes referred to as alley cropping) will accelerate the regenerative process by including forest trees as a component of the total system. In this context agroforestry systems (land-management systems in which trees and shrubs are combined with agricultural food and feed crops) become extremely important. This approach does not require drastic adjustment to new management practices by farmers and therefore causes only minimal disruption of their way of life. More research and extension activities are required in order to facilitate the adoption of these techniques.

When asked specifically what sort of instructions they expected from the extension service in order to develop their upland farming component, most farmers gave similar answers. For example, they expected formal training on new cultivation methods and also provision of equipment such as weeders, seeders and sprayers and other inputs. These responses reflected the unavailability of institutional mechanisms to meet needs of farmers wishing to improve the upland component of this farming system (Table 6).

The extension service is more geared towards improvement of paddy production. Hence farmers practicing pure chena cultivation and those living in remote areas get very little advice through the extension

service. Those who were exposed to the extension service often lacked financial resources to adopt new technologies since they were not eligible for institutional credit. This clearly points up the need to reorganize the extension service to incorporate upland cultivation.

Availability of marketing facilities. Marketing facilities have played an important role in changing cropping patterns. Good roads and transport facilities are some of the key factors that determine the effectiveness of a marketing system. In certain locations, such as Kahambana where chena farming is done in remote areas, it was revealed that most of the crops grown were for subsistence. Any surplus produce from these remote villages was sold to traders who came to the village and at the village fair. Farmers felt that the prices they received were much lower than the prevailing prices in nearby towns. Although the state operates a floor-price scheme for most agricultural products, in Kahambana and Badagiriya only about one-half of the sample knew about its existence; those who knew the program existed did not know what the prices were. Farmers felt that a higher price is a prerequisite for changing their cropping patterns and cultural practices (Table 7). For example, in Gonnoruwa and Mahakalugolla where farmers are mainly dependent on the upland component with a rapidly declining fallow or no fallow, 47.8% and 40.7% of the respondents, respectively, wanted to practice crop rotation to sustain production, if prices were favorable. A large percentage of farmers in Badagiriya (61.6%) and Kahambana (54.1%) wanted to change to perennial-crop systems if prices were favorable. Farmers felt that if a marketing system provided higher prices through guaranteed prices and if purchasing could be done through institutions such as cooperatives, changes in the farming system could be expected.

Policies with reference to legislation. As was mentioned earlier, despite the government taking stringent measures to curb chena cultivation, forest clearing is taking place more or less unabated. Obviously, legislation alone will not solve the problem. Other factors must be considered in order to make legislation more effective. Farmers' attitudes about legislation to curb chena farming indicated that in the absence of supporting factors such as credit, extension, marketing and legal rights to land, farmers would ignore any legislation. Almost all the farmers indicated that they had received no instructions with regard to stabilization of chenas. Those who have stabilized so far have done so on their own initiative primarily due to the unavailability of land, in some cases due to government regulations, and in response to the market. Therefore, legislation alone would not give rise to a sustainable stabilized agricultural system.

CONCLUSION

Shifting cultivation is a system of farming that is widely practiced in Sri Lanka. While it contributes to national food production, it also has detrimental effects on a vital natural resource, the forests. Over the years chena farming has been undergoing a transformation in which the fallow periods have been diminishing. It is important to understand

this transformation in order to find the factors that are important to making a sustainable upland agricultural system.

This paper contends that besides legislation to curb forest clearing, there are many factors involved in making stabilized upland farming more productive. Legal rights to land that is being cultivated are crucial because such rights would enable farmers to obtain institutional loans for their cultivation practices. In addition, the importance of better marketing facilities cannot be overestimated.

More research on the combined use of agroforestry and new tillage techniques is required. Also, on-farm testing of these techniques before dissemination is important. The extension service, which currently focuses its efforts on rice cultivation, needs to serve the upland component better.

ACKNOWLEDGMENTS

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Table 1. Villages and number of households surveyed.

District	Village	Households in village (No.)	Households surveyed (No.)	Households surveyed (%)
Monaragala	Kahambana	36	36	100
	Mahakalugolla	282	48	17
Hambantota	Badagiriya	298	57	19
	Gonnoruwa	104	48	46
Total		720	189	26

Table 2. Land area cultivated per household, length of fallow periods and reliability of water supply for the four study locations.

	Mahakalugolla	Kahambana	Gonnoruwa	Badagiriya
Land type				
irrigated rice	0.0	0.27	1.51	2.76
upland (chena)	4.79	2.72	3.1	1.75
Length of fallow	short	long	long	short
Reliability of water supply for irrigation	none	none	low	high
Total cultivated land	4.79	2.99	4.61	4.51

Table 3. Reasons given by farmers at the four study locations as to why chena farming is not possible in the future.

Reason	Percentage of farmers reporting			
	Kahambana	Mahakalugoll	Badagiriya	Gonnoruwa
Lack of forest land	55.5	14.3	28.3	38.3
Laws against clearing	4.5	57.1	24	11.7
Migrants	0	14.3	4.3	15.6
Population increase	4.5	9.5	15.2	26.6
Not oriented towards chena	0	4.8	4.3	0
Loss of fertility	4.5	0	17.4	1.7
Weed problems	31.8	0	6.5	1.7
Economic difficulties	0	0	0	5

Table 4a. Average labor use per farm household (person-days) for the 1982/1983 maha season.

Location	Type of labor					
	Family	Labor exchange	Day-hires	Permanent	Migrant	Total
Kahambana	251.5	0.3	66.3	0.0	6.5	324.6
Mahakalugolla	219.7	24.4	19.7	0.1	0.3	264.2
Gonnoruwa	264.9	3.3	66.0	12.3	3.6	350.1
Badagiriya	254.0	6.9	96.5	0.0	4.1	361.5

Note: The maha is the primary crop season, corresponding to the northeast monsoon rains.

Table 4b. Labor use (person-days/acre) for the 1982/1983 maha season.

Location	Shifting cultivation	Irrigated rice cultivation
Kahambana	108.5	- -
Mahakalugolla	55.1	- -
Gonnoruwa	72.5	75.5
Badagiriya	162.2	34.3

Note: The maha is the primary crop season, corresponding to the northeast monsoon rains.

Table 5. Length of fallow period of the chena before being cultivated.

No. of years fallowed	Percentage of farmers reporting			
	Mahakalugolla	Kahambana	Gonnoruwa	Badagiriya
2	2.1	5.7	6.2	7.4
3-5	27.1	45.7	45.8	31.5
6-10	0.0	28.6	27.1	11.1
11-15	0.0	8.6	0.0	13.0
More than 15	0.0	11.4	4.2	9.2
No fallow	70.8	0.0	16.7	27.8

Table 6. Kinds of services that farmers expected from the extension service in order to develop chena farming.

Type of service	Percentage of farmers reporting			
	Badagiriya	Gonnoruwa	Kahambana	Mahakalugolla
Visit the farm and advise as needed	2.7	21.7	7.5	8.5
Train on new technology	42.4	30.4	13.4	41.5
Provide equipment and inputs	42.4	23.9	41.8	45.1
Help to obtain credit facilities	1.4	19.6	17.9	4.9
Provide more extension officers	2.8	2.2	0.0	0.0
Other	8.2	2.2	19.4	0.0

Table 7. Percentage of farmers, by study location, who would change their farming practices if price incentives existed.

Method	Percentage of farmers reporting			
	Badagiriya	Gonnoruwa	Mahakalugolla	Kahambana
Crop rotation	13.3	47.8	40.7	2.7
Permanent cropping	61.6	23.3	34.0	54.1
Increasing value of production	11.7	13.0	2.2	21.6
Farming high-value crops	6.6	2.9	4.4	18.9
Use modern methods	5.0	13.0	16.5	0.0
Other	1.7	0.0	2.2	2.7

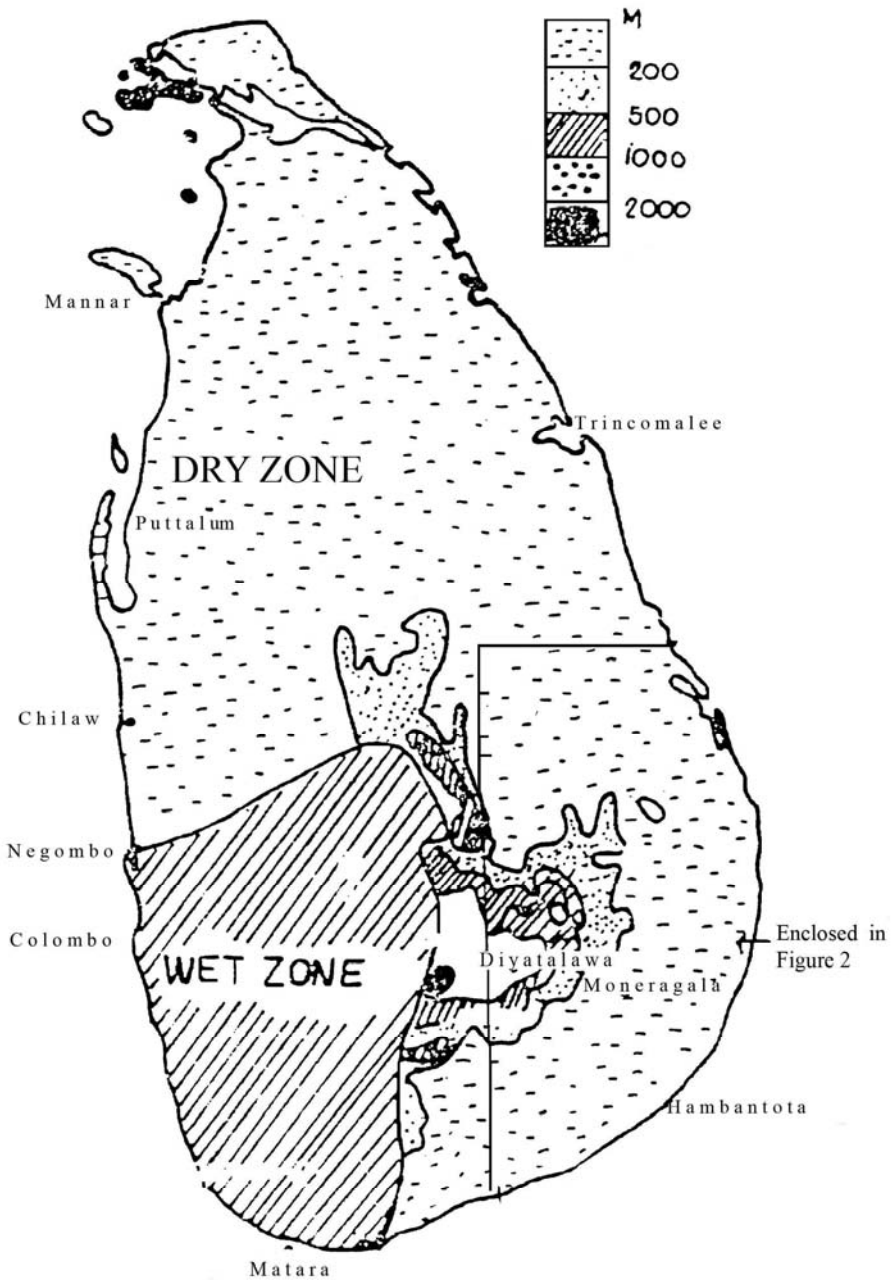

Fig. 1. Map of Sri Lanka showing study districts and agroclimatic zones.

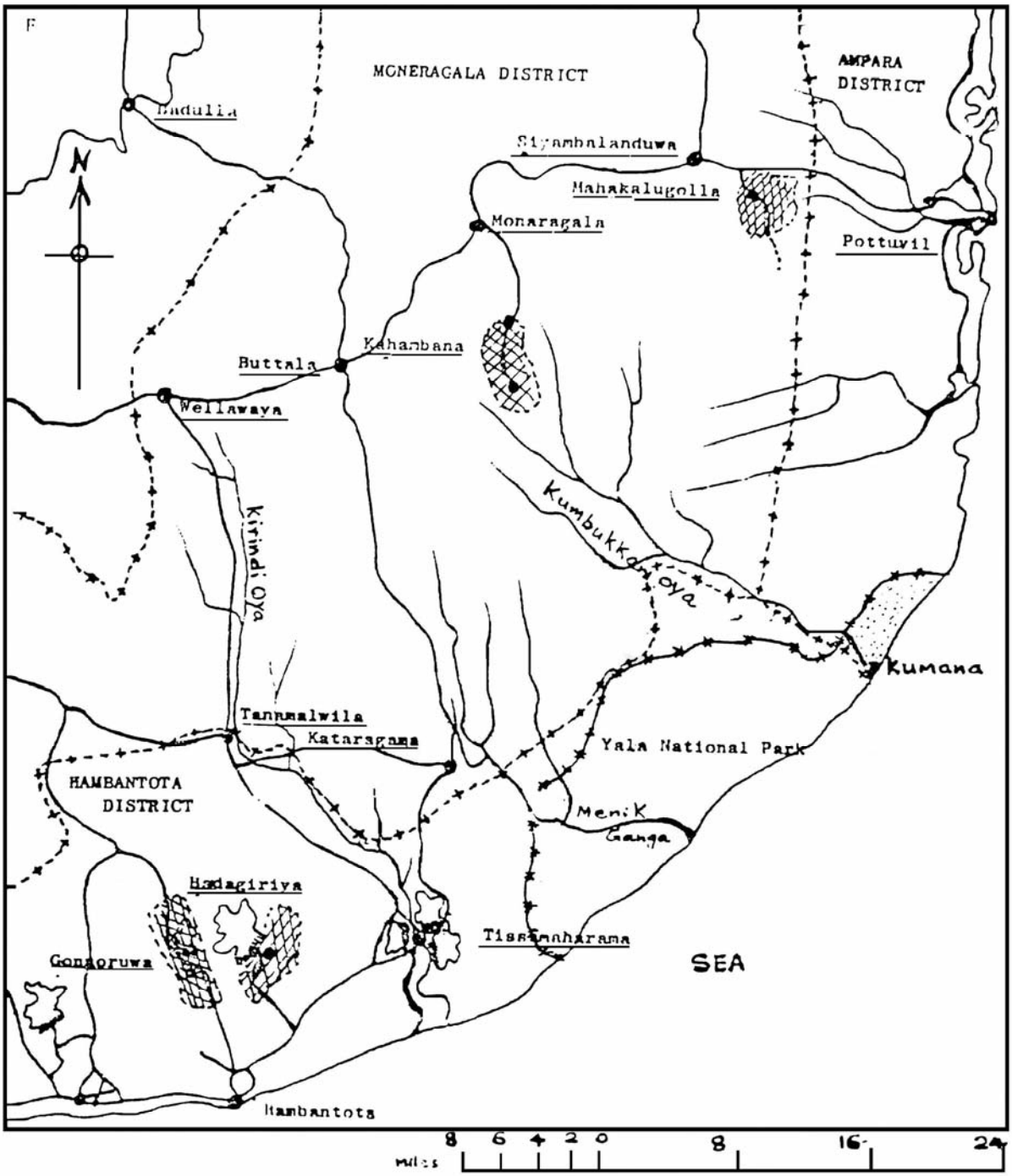

Fig. 2. Map showing study villages

Legend

Study location

Main road

District boundary

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FARMING SYSTEMS RESEARCH AND EXTENSION: MACROECONOMIC ANALYSIS OF MICROECONOMIC DEVELOPMENT

Wilmer M. Harper, Rossana Alvarez de Ayala and Hilda Leonila Claros[1]

INTRODUCTION

Farming systems research and extension (FSR/E) emerged in the 1970s as the premier approach for development projects that focused on small-farm production units (Norman, 1980). Two branches of FSR/E evolved: upstream and downstream (Gilbert et al., 1980). Upstream FSR/E referred to basic research conducted in an experiment station atmosphere to generate new ideas and inputs for downstream FSR/E. Programs of applied or adaptive research conducted jointly by the farmer and the researcher within the farmers' production environment were designated downstream FSR/E. Downstream FSR/E selected among upstream FSR/E outputs or worked for a refinement of existing technology or practices selected by the FSR/E program as most appropriate for and acceptable to the producer.

As practiced in most developing countries, FSR/E has strived to produce ideas and technologies for the improvement of the physical output of individual producers within a micro context. However, it is not axiomatic that this approach will improve the economic welfare of farmers. The final outcome will depend upon the profitability of the technology and the individual producers' opportunities to reallocate their resources to obtain the highest net returns. Although user orientation is a necessary condition for FSR/E, pursuit of this approach to the exclusion of larger macrosystem issues limits the potential of FSR/E and may result in its decline.

Donor support appears to be shifting from FSR/E toward a macropolicy focus. This shift may be attributed, at least in part, to the lack of FSR/E program efforts to establish links to the macrosystem and to a lack of FSR/E analysis within a macro context.

THE PROBLEM

The need to import basic foods such as corn (Table 1) prompted the government of Honduras to pursue policies to increase domestic production of corn, rice, sorghum and red beans. To further these policies, several research and support activities have been undertaken to enhance and further develop FSR/E within the agricultural-research-and-extension community.

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[1]Associate Professor, graduate student, and former graduate student, respectively, Department of Agricultural Economics and Agricultural Business, Agricultural Experiment Station, New Mexico State University, Box 3169, Las Cruces, NM 88003, U.S.A.

The Honduran philosophy and expression of FSR/E has taken a very basic, applied approach. The emphasis has been on variety testing, fertilizer trials and herbicide and insecticide tests for use at the small-farm level. However, the grain-production-and-marketing system is more complex than is suggested by this focus or its agronomic production aspects.

The small farms in Honduras produce a large portion of the national supply of corn; however, these farms have little or no storage capacity. During the harvest period, the price of corn falls as large quantities of corn are placed on the market (Table 2). As a consequence, most corn produced by the small farms is sold at low prices.

The Honduran Agricultural Marketing Institute (IHMA) manages a series of government silos and purchases and sells grain to moderate the seasonal fluctuations of grain prices. However, the IHMA cannot eliminate seasonal price fluctuations, and its program is not directed toward the small-farm production unit. Under these market conditions, corn from small farms is purchased by intermediaries who have storage facilities; farm families receive lower prices for corn than if they could sell directly to IHMA. As the corn market moves through its annual cycle, the market price of corn increases until it reaches a seasonal high just prior to the beginning of the harvest season (Table 2). Since farm families with small holdings do not store corn, they must purchase corn for consumption at these high prices. They therefore must allocate a large portion of their income to food purchases, reducing their consumption of other goods and services.

The country-wide program of on-farm research conducted by the Honduran Ministry of Natural Resources (MNR) has supported the national goal of increased production of basic grains. However, this research agenda contains potential problems for agricultural producers. Increasing production may result in lower prices at harvest and prevent producers from reaching projected increases in income. If the price elasticity is greater than one, the sale of larger quantities will result in lower total revenues for the producer. This situation may be mitigated if producers do not have to sell their corn at the low harvest prices or if the increased production is accompanied by increased productivity and reduced per-unit costs of production.

An FSR/E project in Honduras, the Honduras Agricultural Research Project (HARP), found that farmers take the market price for corn and IHMA's announced purchase price for corn into consideration when deciding what crops to plant in the coming year. (HARP is a joint project implemented by the MNR and New Mexico State University (NMSU) under a contract with USAID. NMSU was the Consortium for International Development's lead university on the contract.)

HARP attempted to identify technologies that could be implemented by producers and that would increase farm-family incomes given the constraints of the macroeconomic system for agricultural products in Honduras. A technology was identified that would allow producers in the target area to receive higher prices for their output and that would contribute to the national goal of increased quantities of corn in the

market. However, the project contract ended, which prevented the complete testing and implementation of the technology.

This paper evaluates the potential impact of the proposed technology on individual producers and elaborates a conceptual framework for evaluating the effects of supply-stabilizing technologies on social welfare. Application of FSR/E to a macroeconomic problem demonstrates the importance of FSR/E contributions to understanding the implications of technology on the economic welfare of society.

PRIOR STUDIES

The prices of agricultural commodities in most developing economies display a cyclical pattern with prices rising to a peak just prior to harvest and falling to a yearly low during the primary harvest season. Seasonal price fluctuations have been studied in the United States and have been shown to result in lower social welfare than would accompany more stable prices. Konandreas and Schmitz (1978) showed that U.S. producers and consumers taken together would benefit from grain-price stabilization. However, the gains and losses from price stabilization are dependent upon the source and magnitude of the price instability. Masell (1969) found that benefits to one group or another depend upon the source of the random price fluctuation. He found that if the random price fluctuation is due to fluctuations in supply, then producers will benefit from price stabilization. Tweeten (1979) demonstrated that a reduction in price oscillations resulting from supply fluctuations will improve the welfare of society. Tweeten and Plaxico (1974) found that consumers were willing to pay slightly higher prices to obtain more stable prices.

THE PROPOSED TECHNOLOGY

The majority of farms do not have storage facilities for their entire crop; therefore, farmers sell most of their crop as soon as possible after removing it from the field. Corn that is physiologically mature is left in the field for 1 to 2 months to reach the desired level of moisture content. The corn is then removed from the fields and marketed during October, November and December.

Individual Benefits

A nontraditional dryer-and-storage system was developed that could be used by small-farm production units. The system consisted of a dryer that could be fueled by wood or the cobs and refuse from the corn plants. The dryer was capable of serving approximately 10 farms.

The new technology would not change the traditional methods of production preceding the removal of the corn from the field. Therefore, a partial-budget approach was used to determine the costs and returns (to a farm) of the new technology. Benefits to individual producers were evaluated using the mean values for corn yield and area cultivated obtained by the HARP sondeo in the Yoro region of northern Honduras

(Bertelsen et al., 1985). Construction and operation costs were experimental and require further verification before a policy recommendation can be made. Construction costs were based upon the construction of experimental dryer units in the Yoro area. The fuel costs were based upon experimental drying; it was assumed that a portion of the cobs would be used for fuel.

The returns to a 14-ha farm are illustrated in Table 3 for the 1982/1983 production period. Early removal of the grain from the field resulted in decreased insect, rodent and bird damage. Coupled with the lower moisture content allowed by drying, the reduced field damage and infestation resulted in lower postharvest losses. Four price scenarios were used to evaluate the profitability of the technology. Two of the scenarios (IA and IB) used the average price for November and differed with respect to the assumption of the reduction in postharvest loss, 5% and 10%, respectively. November was chosen because it is midway through the harvest season and is traditionally the month in which the lowest price occurs (Table 2). The remaining scenarios (IIA and IIB) used the average price for August in conjunction with a 5% or 10% reduction in postharvest loss. August was chosen because it is 2 months prior to the onset of traditional harvest, when prices are relatively high.

Following the analysis in Table 3, the returns for the four scenarios were estimated in current values for the 1978/1979 through 1982/1983 production periods (Table 4). In 14 out of 20 cases, the return to the producer in 1 year exceeded the cost of the technology. Only in the first scenario where the lowest annual price and a 5% reduction in postharvest losses were assumed did the cost always exceed the returns for 1 year. If postharvest losses were reduced by 10% or more or if farmers were able to take advantage of higher prices before the traditional harvest season began, the corn dryer would be profitable. Based on these results it appears that producers have a significant incentive to try the technology. In addition, the technology requires no change in production practices other than removing the grain from the field at an earlier date. The technology has been tried experimentally in the area by farmers; it appears to meet all conditions for extension throughout the system.

Social Welfare Implications

Lacking storage facilities, small production units sell their grain soon after harvest for the least favorable annual price (Table 2). The middlemen purchase the corn in a glutted market and hold it for resale at more favorable prices later in the season.

The supply and demand conditions for corn produce an annual cycle that approximates the framework presented in appendix A. If the long-term supply were stabilized it would approach S*S*. Producers sell their product at a price that approximates prices resulting from a S_L. Since middlemen remove much of the product from the market, consumers purchase corn at a price that approximates prices resulting from S_u. Given Tweeten's conceptual framework, Honduras experiences a reduction in social welfare resulting from the swings in corn prices that are associated with the changes in the quantity of corn marketed.

Since the technology was found to be financially beneficial to producers, an analysis was conducted to determine if gains in social welfare could justify government support for the technology.

Supply and demand functions for corn were estimated using the data in appendix B. The resulting estimates were:

$$Q_d = 14{,}044{,}973.64 - 1.304\ S_{sor} - 230{,}289.85\ P_c \qquad (1)$$

(7.638) (-2.526) (-2.674)

$R^2 = 0.69$ $F = 4.378$ Durbin-Watson D = 1.514

$$Q_s = 4{,}722{,}146.18 + 283{,}646.36\ P_c \qquad (2)$$

(3.070) (2.630)

$R^2 = 0.39$ $F = 6.918$ Durbin-Watson D = 1.795

where: Q_d = quantity corn demanded
Q_s = quantity corn supplied
S_{sor} = supply of sorghum
P_c = price of corn

The numbers in parentheses are the t-values for the respective coefficients. All coefficients were significant at the 10% level of significance. Using the supply and demand functions, an equilibrium price for corn was estimated (appendix B).

For the period from 1978/1979 to 1982/1983, the market prices for corn during November and August tended to be below and above the equilibrium price, P*. The analysis assumed that at these prices the quantity supplied would approximate the conditions of S_L and S_u, respectively (appendix A).

The gain in producer surplus that would accompany early harvest and marketing was estimated as follows. Using the November price as P_1, the supply equation, equation (2), was used to estimate the quantity supplied, Q_{s1} The actual quantity supplied, Q_a, was assumed to lie on S_1 and $Q_{11} < Q_a$. The analysis assumed S_1 to have the same slope as S*S*. Given S_1, the quantity supplied at P*, Q_{12} was estimated as

$$Q_{12} = Q^* + (Q_a - Q_{11}) \qquad (3)$$

where Q* is the equilibrium quantity associated with equilibrium price P*. The monthly prices were for periods that did not correspond to the calendar year of the quantity-supplied data. Therefore, the reported quantity-supplied data were converted to similar periods by taking the simple average of the 2 relevant years, and the derived figures were used in equations (3) and (4). The supply curve, S_u, was then used to estimate the producer surplus associated with a reduction in supply fluctuation that would result in P*. The producer surplus was estimated for the periods extending from 1978/1979 through 1982/1983 (Table 5).

The gain in consumer surplus associated with early harvest and marketing was estimated in a manner analogous to that for producer surplus. Using the August price as P_u, the supply equation was used to estimate a quantity supplied, Q_{u1}. The actual quantity supplied, Q_a, was assumed

to lie on S_u and $Q_{u1} > Q_a$. The analysis assumed that S_u had the same slope as S*S*. Given S_u, the quantity supplied at P*, Q_{12}, was estimated as

$$Q_{u2} = Q^* - (Q_{u1} - Q_a) \quad (4)$$

where Q* is the equilibrium quantity associated with equilibrium price, P*. The supply curve, S_u, was then used to estimate the consumer surplus associated with a reduction in supply fluctuation that would result in P*. The consumer surplus was estimated for the periods extending from 1978/1979 to 1982/1983 (Table 5).

The equilibrium price was then used to estimate the increases in social welfare that would result under various assumptions concerning the probability of each price (P_u and P_1) occurring. The results of the sensitivity analysis are presented in Table 5. The total benefits to society depend upon the probability associated with the occurrence of S_u and S_1. In only one case, consumer surplus 1981/1982, would the reduction in supply fluctuation have resulted in a reduction in consumer or producer surplus. Under the alternative scenarios for the probability of the occurrence of S_1 and S_u, the increase in social welfare ranges from -802,985 Lps. to 19,261,692 Lps. (2 lempiras equal US$1). For the five periods analyzed, the total increase in social welfare ranges from 10,861,387 Lps. to 37,071,170 Lps.

This analysis assumes that the reduction in supply variation is sufficient to result in P*. To the degree that P* is not achieved, the estimated surpluses would be reduced. Therefore, the values in Table 5 should be taken as the maximum values that could be achieved.

CONCLUSIONS

The corn-drying technology would have resulted in benefits to individual producers under most of the analytic assumptions. At the producer level, 20 alternatives were considered. Thirteen of the alternatives resulted in net increases in producer income, and 19 of the alternatives returned more than one-half of the annual cost of construction, maintenance and operation. This would appear to provide strong incentives for producer participation and indicates a low risk to producers.

The changes in social welfare are also favorable. Only the consumer surplus for 1981/1982 decreased under the probability scenarios. The aggregate for the five periods was positive under all probability scenarios. Given the findings of Tweeten and Plaxico (1974) concerning consumer willingness to pay for price stability, the small decrease in consumer surplus observed in the 1981/1982 estimates might not be perceived as a real decrease by consumers.

The results provide support at the macroeconomic level for government support for programs that provide stability of supply as well as increased supply. The framework developed in the analysis may be refined and adapted to the analysis of FSR/E program impacts on the

macroeconomy. This type of analysis would provide the basis for continued development of FSR/E programs.

The data problems encountered by this study are not unique to developing economies; however, they are exacerbated by the conditions under which data are collected and maintained in developing economies. If FSR/E analyses are to expand to routinely include macroeconomic considerations, FSR/E programs must begin to maintain databases to support these analyses.

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APPENDIX A

With a fixed demand curve D*D* (figure A1) and supply varying randomly with probability 0.5 each for and S_u, a costless policy that tends to stabilize supply at S*S*, thus holding price at P*, results in an increase in net benefits to the society. When occurs, if price is increased from P_I to P* through program action that moves toward S*S*, producers gain (9 + 10 + 11 + 12 + 13 + 14 + 15), and consumers lose (9 + 10 + 11 + 12 + 13). There is, however, a net gain to society equal to (14 + 15). When S_u occurs, if price is decreased from P_u to P* through program action that moves S_u toward S*S*, producers lose (2), and consumers gain (2 + 3 + 4) . Under this condition, the net gain to society is equal to (3 + 4). Based upon Just's (1975) analysis, the average net gain to society over the long run is 0.5 (3 + 4 + 14 + 15) when S_u and S_1 have equal probabilities.

[Figure Al was unavailable for printing.]

APPENDIX B

Data used to estimate supply and demand functions and the equilibrium price resulting from those equations.

SUPPLY ESTIMATION DATA SET

Year	Production	Price[a] of Corn
1974	7,161,100	7.38
1975	7,896,800	12.90
1976	6,700,000	10.00
1977	8,408,500	13.12
1978	9,806,200	15.26
1979	7,181,500	14.30
1980	8,540,700	12.66
1981	10,946,600	13.88
1982	10,596,432	16.50
1983	8,346,822	16.50
1984	8,949,884	16.50
1985	9,405,000	16.50
1986	9,072,000	16.50

DEMAND ESTIMATION DATA SET

Year	Sorghum supplied	Price of	Quantity of corn
1979	782,226	19.83	8,063,000
1980	1,072,391	18.86	8,440,700
1981	1,242,440	17.83	8,597,200
1982	698,862	19.10	8,566,500
1983	955,861	15.77	8,884,167
1984	1,041,561	14.99	9,353,920
1985	255,522	19.82	9,458,701

QUANTITY CORN SUPPLIED PARAMETER ESTIMATES

Variable	Coefficient
Intercept	4,722,146.18
Price of corn	283,646.36

Qs = 4,722,146.18 + 283,646.36 Pc
(3.070) (2.630)

R^2 = 0.39 F = 6.918
Durbin-Watson D = 1.795

QUANTITY CORN DEMANDED PARAMETER ESTIMATES

Variable	Coefficient
Intercept	14,044,973.6
Sorghum supplied	-1.3045467
Price of corn	-230,289.85

Qd = 14044973.64 - 1.304567 Ss -230,289.85 Pc
(7.638) (-2.526) (-2.674)

R^2 = 0.69 F = 4.378
Durbin-Watson D = 1.514

EQUILIBRIUM PRICE OF CORN USING AVERAGE QUANTITY OF SORGHUM SUPPLIED

Qs = Qd

4,722,146.18 + 283,646.36 Pc = 14,044,973.64 - 1.304567 Ss - 230,289.85 Pc
513,936.21 Pc = 9,322,827.46 - 1.3045467 Ss
513,936.21 Pc = 8,195,538.28
Pc = 19.95

[a]1974 to 1981.
1982 to 1986.

Table 1. Volume of corn imports: Honduras, 1960 to 1982.

Year	Quantity (thousands of kilograms)
1960	184
1961	1,655
1962	147
1963	881
1964	868
1965	1,950
1966	1,105
1967	3,436
1968	1,969
1969	223
1970	449
1971	495
1972	107
1973	1,894
1974	367
1975	42,986
1976	665
1977	12,813
1978	37,116
1979	7,393
1980	48,284
1981	17,669

Source: Banco Central de Honduras.

Table 2. Monthly corn prices (in lempiras per quintal)[a] for Honduras, 1965 to 1984.

Time period	Sept.	Harvest season Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.
1965/1966	6.25	5.07	4.81	4.57	4.84	5.11	5.19	5.46	5.28	5.40	5.39	5.31
1966/1967	4.71	4.36	3.36	5.08	5.86	6.55	7.06	6.93	6.56	7.91	8.51	10.09
1967/1968	9.33	6.40	5.88	6.14	6.49	6.83	7.75	8.25	7.80	7.35	7.78	7.51
1968/1969	6.46	5.36	5.22	5.04	5.07	5.88	5.92	5.97	5.82	5.84	5.39	5.87
1969/1970	6.46	4.73	4.45	4.73	5.35	5.75	6.20	6.84	6.83	7.57	9.66	12.47
1970/1971	5.77	4.84	4.59	4.81	5.03	5.53	5.47	5.35	5.75	5.90	6.40	6.79
1971/1972	8.31	6.01	5.51	5.35	5.74	6.00	5.98	6.34	5.75	5.88	7.48	8.34
1972/1973	6.44	6.92	5.82	5.88	6.08	6.97	9.14	9.17	8.88	8.64	8.31	8.14
1973/1974	8.13	6.17	6.13	6.24	7.09	7.82	9.14	9.53	9.76	9.64	9.96	8.10
1974/1975	7.76	9.42	9.54	9.26	10.02	10.21	11.49	13.33	12.57	13.83	18.88	22.03
1975/1976	9.61	16.00	13.60	12.50	10.74	9.22	10.13	9.03	10.97	9.08	9.62	8.84
1976/1977	21.34	10.44	9.52	10.28	16.38	17.48	22.01	18.44	18.91	18.95	19.75	22.05
1977/1978	10.19	13.43	12.57	13.00	17.72	18.66	18.10	17.77	15.82	16.09		
1978/1979	20.70	11.60	11.22	11.22	13.19	13.19	13.45	13.99	14.31	15.05	15.76	16.39
1979/1980	15.75	15.96	14.01	14.86			21.81	22.83	21.85	21.15	22.95	25.28
1980/1981	17.55	17.69	15.99		17.47	18.25	18.67	19.23	18.98	18.17	19.23	19.51
1981/1982	20.41	18.74	16.60	16.13	15.55	15.85	19.38	18.51	17.73	17.91	18.84	19.35
1982/1983	18.97	16.06	14.30	15.03	16.55	17.85	19.53	19.80	19.19	20.55	22.74	28.63

[a]One quintal equals 100 lb. Two lempiras equal U.S.$1.

Table 3. Annual partial budget (in lempiras)[a] for a small-farm dryer/storage system under alternative assumptions, 1982/1983 season.

COSTS		
Dryer		
Construction costs & interest[b]	285.60	
Transportation of materials	20.00	
Operation & maintenance	200.00	
Fuel	427.00	
		Total 932.60
RETURNS[c]		
Using seasonal low price (14.30 Lps.)		
Postharvest loss reduced from 15% to 10%		500.50
Postharvest loss reduced from 15% to 5%		1,001.00
Using price 2 months prior to seasonal low price (28.63 Lps.)		
Postharvest loss reduced from 15% to 10%		
- value of reduced loss	1,002.05	
- increased value of crop due to early sale	10,031.00	
Total		11,033.05
Postharvest loss reduced from 15% to 5%		
- value of reduced loss	2,004.10	
- increased value of crop due to early sale	10,031.00	
Total		12,035.10

[a]Two lempiras equal U.S. $1.
[b]Assumes construction cost of 1,000 Lps. amortized over a 5-year period at an interest rate of 15%.
[c]Assumes an average yield of 50 quintals (2,273 kg) of maize per hectare as determined by the HARP sondeo.

Table 4. Gross returns to corn dryer under alternative postharvest loss and price scenarios for corn, 1978/1979 through 1982/1983.

Time period	Returns (values in lempiras)[a]			
	Scenario IA	Scenario IB	Scenario IIA	Scenario IIB
1978/1979	392.70	785.40	4,192.65	4,766.30
1979/1980	490.35	980.70	8,773.80	9,658.60
1980/1981	559.65	1,119.30	3,146.85	3,829.70
1981/1982	581.00	1,162.00	2,602.25	3,279.50
1982/1983	500.50	1,001.00	11,033.05	12,035.10

[a]Two lempiras equal U.S.$1.

Table 5. Producer surplus (PS) and consumer surplus (CS), in lempiras,[a] resulting from alternative probabilities of the occurrence of fluctuations in the supply curve for corn in Honduras.

	1978/1979		1979/1980		1980/1981		1981/1982		1982/1933		
	Individual	Increased social welfare	Individual	Increased social welfare	Individual	Increased social welfare	Individual	Increased social welfare	Individual	Increased social welfare	Five-period aggregate increased social welfare
Producer surplus (PS)	4,944,449		1,872,266		11,079		559,144		198,226		
Consumer surplus (CS)	194,486		18,814,378		913,007		-954,333		21,379,855		
Prob. 0.5 PS and 0.5 CS		2,569,468		10,343,322		462,043		-197,595		10,789,041	23,966,279
Producer surplus (PS)	4,944,449		1,872,266		11,079		559,144		198,226		
Consumer surplus (CS)	194,486		18,814,378		913,007		-954,333		21,379,855		
Prob. 0.4 PS and 0.6 CS		2,094,471		12,037,533		552,236		-348,892		12,907,203	27,242,501
Producer surplus (PS)	4,944,449		1,872,266		11,079		559,144		198,226		
Consumer surplus (CS)	194,486		18,814,378		913,007		-954,333		21,379,855		
Prob. 0.3 PS and 0.7 CS		1,619,475		13,731,744		642,429		-500,290		15,025,366	30,518,724
Producer surplus (PS)	4,944,449		1,872,266		11,079		559,144		198,226		
Consumer surplus (CS)	194,486		18,814,378		913,007		-954,333		21,379,855		
Prob. 0.2 PS and 0.8 CS		1,144,479		15,425,956		732,621		-651,638		17,143,529	33,794,947
Producer surplus (PS)	4,944,449		1,872,266		11,079		559,144		198,226		
Consumer surplus (CS)	194,486		18,814,378		913,007		-954,333		21,379,855		
Prob. 0.1 PS and 0.9 CS		669,482		17,120,167		822,814		-802,985		19,261,692	37,071,170
Producer surplus (PS)	4,944,449		1,872,266		11,079		559,144		198,226		
Consumer surplus (CS)	194,486		18,814,378		913,007		-954,333		21,379,855		
Prob. 0.6 PS and 0.4 CS		3,044,464		8,649,111		371,850		-46,247		8,670,878	20,690,056
Producer surplus (PS)	4,944,449		1,872,266		11,079		559,144		198,226		
Consumer surplus (CS)	194,486		18,814,378		913,007		-954,333		21,379,855		
Prob. 0.7 PS and 0.3 CS		3,519,460		6,954,900		281,657		105,101		6,552,715	17,413,833
Producer surplus (PS)	4,944,449		1,872,266		11,079		559,144		198,226		
Consumer surplus (CS)	194,486		18,814,378		913,007		-954,333		21,379,855		
Prob. 0.8 PS and 0.2 CS		3,994,456		5,260,688		191,465		256,449		4,434,552	14,137,610
Producer surplus (PS)	4,944,449		1,872,266		11,079		559,144		198,226		
Consumer surplus (CS)	194,486		18,814,378		913,007		-954,333		21,379,855		
Prob. 0.9 PS and 0.1 CS		4,469,453		3,566,477		101,272		407,796		2,316,389	10,861,387

[a]Two limpiras equal U.S.$1.

SUPPORT OR SUBVERSION: THE RELATIONSHIP BETWEEN FSR AND TANZANIA'S AGRICULTURAL POLICY OBJECTIVES

Larry S. Lev and Ann L. Shriver[1]

INTRODUCTION

After a relatively brief 5 to 7 years in the spotlight, the initial burst of enthusiasm for farming systems research (FSR) has begun to fade, and donor funding levels are stagnant or dropping. Some observers are heartened to see this de-emphasis of the FSR approach since they believe that it has attracted agricultural research funds that could be better used elsewhere (Eicher, 1986). Others, however, believe that the FSR approach and methods will continue to have an important influence on agricultural research and extension activities in developing countries.

This article examines through the use of a case study the relatively neglected area of the relationship of the FSR approach to a broader scope of national policy objectives and actions. The consideration of the historical record of Tanzanian agricultural policies over the past 25 years provides an opportunity to consider in a hypothetical fashion which of the broad range of policies pursued over that period would have been supported by a functioning FSR program and which subverted (and vice versa). Although FSR practitioners and national policymakers often differ markedly in their perspectives on rural development, an improvement in their mutual understanding should provide substantial benefits to both sides.

Simmonds (1986) subdivided the diverse activities included under the general heading of FSR into three categories:

- FSR "sensu stricto" — the academic activity of conducting in-depth studies of farming systems as they exist

- on-farm research with a farming systems perspective (OFR/FSP) — the use of a marginalist, farmer-oriented approach to agricultural research

- new farming systems development (NFSD) — the process of developing revolutionary new systems rather than stepwise changes

Throughout the text, we use the term FSR to refer to Simmonds' second category, since this remains the most widely practiced version of FSR. Reference is also made to NFSD in the context of the Tanzanian case study.

[1]Department of Agricultural and Resource Economics and Office of International Research and Development, Oregon State University, Corvallis, U.S.A.; International Institute of Fisheries Economics and Trade, Oregon State University, Corvallis, U.S.A.

FSR supporters believe that the use of its methods can accelerate the rate of technology development and adoption through a more accurate reflection of farmer constraints and interests. A second, less emphasized benefit of the FSR approach is the influence that FSR practitioners can have on the development of a suitable infrastructure and policy environment for small-scale production. This has been termed farming systems infrastructure and policy support, or FSIP, (Caldwell, 1984) and is considered in greater detail in the next section.

Overall, FSR can perhaps best be understood as a group of skills or tools that FSR teams, in cooperation with farmers, use to tinker with and improve upon existing farming systems. The initial mix of social and biological FSR tools has proven itself successful in promoting marginal, short-term improvements for broad groupings of farmers.

LIMITATIONS OF FSR

This paper belongs among a series of critiques and(or) extensions that have been developed to point out shortcomings of this standard approach and to suggest additional tools of value for the FSR approach. Four categories of critiques are described next:

Time Frame/Environmental Impact (Maxwell, 1986; Johnson, 1984; Lev and Campbell, 1987)

These articles, which were written primarily from a natural resource perspective, express a concern that FSR, as it is generally applied, assumes a static farming system. As a consequence, the danger exists that the technologies developed may provide short-term gains while at the same time undermining the long-term productivity of the farming system. The solution proposed by these authors requires the incorporation of a longer timeframe and an improved understanding of changing resource conditions into the set of factors that influence the design, testing and evaluation of the FSR interventions. Maxwell identifies this as the task of "hitting the moving target."

Two concerns with these suggestions should be noted. First, they would increase the complexity of the research process and therefore reduce the speed and increase the cost of technology development and dissemination. Second, it may prove more difficult to foster farmer involvement and enthusiasm for interventions that provide long-term but perhaps not short-term benefits to the target group of farmers.

Intrahousehold Considerations (Berry, 1986; Guyer, 1986; Jones, 1986; Tibaijuka, 1986)

These articles, which focus on household studies, challenge the standard FSR assumption that the family is the appropriate unit of analysis. The authors agree that since decisions are made by and benefits accrue to individuals within households, it is necessary to initiate and evaluate FSR interventions at the more disaggregated individual level. Without this more detailed analysis, the acceptability of proposed technologies and(or) their value to specific clientele groups (women being a prime

example) will be dramatically reduced. As when using the longer timeframe analysis, the assumption is that the additional research cost involved will be more than offset by the increased benefits that result from an improved understanding of the implications of introducing new technologies.

Intrasocietal Considerations (Garrett, 1984, 1986)

Garrett's critique calls for the modification of the simplistic view of society that is assumed by the FSR approach. Although FSR, through the use of the recommendation domain concept (Tripp, 1986), recognizes the existence of multiple groups within society, the approach devotes little attention to the interrelationship of these different groups and how these relationships will be influenced by proposed technological interventions. Garrett argues that it is only by paying more attention to the structure of society that FSR teams will be better able to predict and influence the manner in which technical changes are manifested as they move through society.

National Policy Objectives

This paper focuses on a fourth area that has not received sufficient consideration in FSR work to date: the nature and range of interactions between FSR practitioners and national policymakers. As detailed in the sections that follow, national policies and objectives and an FSR approach are in many instances mutually supportive. Circumstances may arise, however, in which national or societal concerns and those that come out of a localized, farmer-oriented FSR effort are at cross purposes. In contrast to the lack of consideration of these issues within the mainstream of FSR literature, Fresco (1984) noted that the francophone approach to FSR does specifically focus on the integration of FSR efforts within a broader context of regional development.

In general terms, the argument developed here is that little effort has been devoted to the delicate task that FSR teams face of balancing the interests of individual families versus those of the nation as a whole. If inadequate attention is paid to the clientele group, the FSR effort will fail due to its lack of involvement. If sufficient attention is paid to the objectives of national policymakers, the FSR program will be hampered by political animosity and the lack of resources and supporting policies.

Day (1978) and Ruttan (1987) observed that agricultural scientists are often unwary revolutionaries who pay little attention to the social implications of their work. It is in sharp contrast with that observation that we recognize a distinct conservative and cautious tendency within the tenets of the FSR approach. This occurs because FSR focuses on marginal rather than major changes.

The following questions are among those that deserve more careful consideration:

- Does the relevance and role of the FSR approach vary as a function of the nature of the ruling political regime?

- To what extent can or should FSR teams attempt to integrate national and farmer objectives when formulating their programs?

- How can FSR teams best provide information for use in the national policy formulation process?

- How responsive should national policymakers be to issues and information that emerge at the local level?

While in certain respects and under certain circumstances the nation can be regarded as the sum of the interests of the individual citizens, this must be viewed as an oversimplification. Consequently, it is normal for the national government to have concerns and objectives that are not shared by the individual households. Therefore, from the societal perspective, using the household as the unit of analysis in FSR may result in inappropriate technology development and policy suggestions.

In a general issue, policymakers often fail to recognize the complexity of agricultural production systems, while FSR practitioners may be poorly prepared to appreciate the range and variability in national policy objectives. Furthermore, it is not clear that FSR, as it is currently practiced, will be equally supportive of the full range of potential policies and objectives. Communication would be improved if both FSR practitioners and national policymakers had a better understanding of what to expect from each other.

The interactions between FSR teams and policymakers may take two forms — the transmittal of observations and suggestions made by the FSR teams up to the policymakers, and the transmittal of policy objectives and information needs from the policymakers down to the FSR teams. Current FSR literature gives little consideration to farming systems infrastructure and policy support (FSIP) or to the process of sending information up from the field level. FSIP is based on the assumption that FSR team members will develop an understanding from the farmer's perspective of nontechnical as well as technical constraints to production. The goal of FSIP is for the team members to communicate these "bottom-up" policy suggestions to those who have the power to act upon them. Thus, in the FSIP process, the team treats as variables many factors (such as prices, marketing options and input availability) that are treated as parameters during the standard FSR process. Since the main focus of FSR has been in the realm of technology development, it is not surprising that many observers continue to regard FSIP as a neglected area (see, for example, Gilbert et al., 1980).

Other observers argue that FSR by its very nature sends a consistent set of messages to governmental leaders. Wallace and Jones (1986) ascribe to FSR a social objective or ideology that is based upon providing a comparative advantage to previously disadvantaged rural populations through the development and dissemination of new technologies and through the removal of external constraints to farmer production.

In summary, FSIP asks "what the country can do for the farmer" but not "what the farmer can do for the country." While this may be a justified

reaction to past abuses, one wonders if there is not a middle course that maintains a concern for national objectives as well.

A major concern related to the potential effectiveness of FSIP is that field-level researchers and extension agents have little or no experience in the upward communication of opinions on policy issues and thus may not be adequately prepared for this new role. Other questions also arise with respect to the implementation of FSIP. Will the policy suggestions emanating from the FSR teams invariably be of the nature of "get off the backs of the farmers"? Who in the government will shoulder the responsibility of pulling together and interpreting all the messages flowing up? How will the reception given these messages vary as a function of the type of political regime in power? These are the some of the issues to be considered in the case study that follows.

The second type of interaction, the transmittal and use of national-level information at the local level, is seldom discussed in any detail in the FSR literature. Policy objectives and directives are generally represented in FSR flowcharts as a black box of exogenous parameters that should be taken into account. Ideally these policy objectives should function as another group of criteria through which the set of possible new technologies are filtered in order to select the most promising ones. How should this be accomplished? How should the information be transmitted? How should the local teams make effective use of this information (and effective for whom)?

In this regard, it is important to recognize the potential for thrusting conflicting roles upon the FSR team members as a result of the broadening of their perspective. The decision by the Tanzanian government in the early 1980s to transfer the extension service from the Ministry of Agriculture to the Prime Minister's Office provides an excellent example of such a conflict. This action, which was later rescinded, added political responsibilities to the extension agents' technical role and as a result dramatically reduced their credibility and effectiveness with their clientele. Since one can easily foresee a policy-motivated FSR team suffering the same fate, it would not be wise to place FSR practitioners in this role of policy exhorters or enforcers. There is thus a lack of symmetry in the role of the FSR team members. While they act as spokespersons for their cooperating farmers in the transmission of information and policy suggestions to policymakers, they should not fulfill a similar role in bringing the government's policies to the countryside but rather should use these policies internally in the development of an appropriate research program.

The following sections examine the potential role of an FSR approach within the changing course of agricultural policy over the past 25 years in the East African nation of Tanzania. This historical review has particular relevance within modern Africa because other nations are currently pursuing similar policies, and thus FSR programs elsewhere on the continent may find themselves in parallel situations.

THE CONTEXT OF TANZANIAN POLICY DEVELOPMENT

This section outlines major elements and objectives of Tanzania's agricultural policy since 1961 and examines whether the use of an FSR-type approach would support or conflict with these goals and policies. Specific examples are drawn from the experience of the Tanzania Farming Systems Project from 1983 to the present.

The wide variations in Tanzanian policy over the last quarter century can be attributed both to shifts in the underlying objectives sought by the government and to changes in the policymakers' beliefs about the net effect of specific policies. In terms of small-scale agriculture, this implies both a normative modification of the role and contribution of the rural peasantry to the country's development and a positive modification of the policy measures that will favor that path of development. At various times, and to various degrees, Tanzanian farmers have been approached with the carrot (incentives), the stick (regulations) and the exhortation (ideas and words).

In some ways, the policy environment has come full circle back to the relatively noninterventionist, free-market ideas that were prominent in the early 1960s. In the interim, agricultural policy has passed through a number of different eras. The first period was marked by the nationalization of large-scale agriculture and a pilot effort to introduce communal production in the form of the "ujamaa" vision of Utopian socialism. This was followed by the massive effort to achieve geographic centralization during the "villagization" period of the early 1970s. The second half of that decade was marked by the dismantling of agricultural marketing cooperatives and local government bodies and the creation of centralized government agencies to perform their functions. It was also a period of stagnant or declining prices paid to producers for export crops. In the mid-1980s, the reestablishment of cooperatives, real producer price increases, new legal provisions allowing villagers to return to scattered farms outside of established central villages and the reintroduction of large-scale commercial farming reversed earlier decisions.

Despite these widespread changes it can still be argued that the set of objectives sought by government policymakers has remained relatively stable. These objectives include the following:

- increased productivity and improved living conditions for the rural population

- a transformation in the mode of production in agriculture in terms of both technology and organization

- the "capturing" or integration of the peasantry into the larger society

- the extraction of surplus and earning of foreign exchange

- the consolidation of decision-making power in the hands of central government

- national food security

- greater equality throughout society

The two factors that have changed are the relative importance attached to each objective and an understanding of the tradeoffs among objectives.

It must be emphasized that Nyerere set out to define a uniquely Tanzanian path of development that was not to be judged by traditional Western standards.

> The vital point is that the basis of socialist organization is the meeting of people's needs, not the making of profit. The decision to devote the nation's resources to the production of one thing rather than another is made in the light of what is needed, not what is most profitable....a successful harlot or a favored slave may be better off materially than a woman who refuses to sell her body, or a man who refuses to sell his freedom. We do not regard the condition of the harlot or slave as being consequently enviable...(Nyerere, 1973)

Nyerere's Tanzania is not a place where one merely adds up incomes across the population to assess the welfare of the country.

Our task here is to examine the potential contribution of a farming systems approach to the achievement of these varying sets of objectives. Some goals, such as the structural transformation of society, the explicit consideration of equality issues and the generation of surplus at the national level are rarely considered explicitly within an FSR program. Can the microscale or client orientation of the FSR approach help in achieving these kinds of objectives, or will FSR-generated interventions and policy suggestions end up subverting government policies in these areas? Subsequent sections address these issues, which are fundamental to the FSR approach's success, acceptance and integration into national research systems.

Independence Through 1973: Ujamaa and Transformation

From independence, the task of relocating Tanzania's scattered rural population into villages was viewed by government officials and expatriate experts alike as a prerequisite for embarking on a viable path of development and increased productivity. The World Bank development plan (which strongly influenced the first Three Year Plan) distinguished between areas where an "improvement" or marginalist approach could be implemented and other areas that were either sparsely populated and semiarid or overpopulated and deteriorating and thus required a more drastic "transformation" approach. This transformation, the experts argued, must involve the resettlement of farmers into centralized villages where extension, credit and social services could be provided and new "improved" patterns of cultivation established (Miti, 1981). The initial resettlement scheme was dropped in 1966, however, due to its failure to achieve support among the peasants whose

"apathy and attachment to outmoded practices" (Kawawa, 1966) it was supposed to overcome.

It was only in 1967 that the idea of a socialist organization of agricultural production was formally introduced with the publication of President Nyerere's paper, "Socialism and rural development," and the Arusha Declaration.

> The essential thing is that the community would be farming as a group and living as a group....The return from the produce of the farm, and from all other activities of the community, would be shared according to the work done and to the needs of the members, with a small amount being paid in taxes and another amount... invested in their own future (Nyerere, 1968)

As pointed out by Coulson (1982), the concept of "ujamaa" (or familyhood) was now linked with the earlier idea of relocation in central villages to provide a dual sense of transformation that included changes in both geographic location and the organization of production. In principle, the new rural sector would provide not only greater production but also increased equality and enthusiasm for socialism. This belief in the advantages and necessity of a socialist transformation of agriculture was (and perhaps still is) widely shared in many circles (Baran, 1968; Amin, 1976; Thomas, 1974).

Initially, no force was to be used to create the villages; they were to be spontaneous responses of the villagers to the education and mobilization efforts of the government and party. Gradually, in response to the reluctance of the scattered rural population to drastically disrupt long-established farms and production systems, the party and government began to exert increasing pressure for the establishment of the new villages. Miti (1981) distinguishes three approaches used during the ujamaa period: the "voluntary, spontaneous, and autonomous" approach of 1967 and 1968, the "inducement and guided" approach of 1969 and the "operational" approach of 1971.

Explanations for the failure of communal farming have ranged from assertions that inadequately prepared party cadres were unable to properly educate the masses about the goals and importance of what was to be accomplished (i.e., poor implementation) (Luttrell, 1971; Cliffe, 1972) to claims that the policy itself was flawed. Miti (1981) points out that "It was mistaken to expect the consensus reached in the services areas to be reproduced in production activities where individual interests were at stake." Regardless of the reasons for the failure of the concept, its lack of acceptability to the rural peasant was clear: Ellman (1975) mentions that of 2,668 villages formed by 1971, only 17 had significant communal production projects under way.

At the TANU Biennial Conference held in 1973, the decision was made to dramatically expand the move into villages while simultaneously de-emphasizing the ujamaa aspects of the new villages. "To live in villages is an order," said Nyerere (Daily News, November 7, 1973), and by 1976 some 13 million people were in compliance with this directive. Estimates of the number of people who were relocated during the

villagization program range from 5 million to 10 million (Hyden, 1980). There is broad agreement that much of this was accomplished by force, involving dumping people in unprepared areas and burning residences to prevent people from returning to their homes (Coulson, 1982). The program resulted in a significant decrease in national agricultural production because in many instances the uprooted families (some were even moved in the middle of the growing season) were resettled on poorer soils and in areas for which they had no prior farming experience (Shao, 1986). Within the new centralized villages, the distance to the fields became a major constraint to production.

Hyden (1980) and Payer (1983) were foremost among those who concluded that the villagization program was primarily about control and that the Tanzanian government had retained the consistent goal of "capturing" the peasantry. Control was to be gained by introducing changes in the production system which, if successful, would integrate the peasant farmers into the monetary economy and force them to specialize, thus becoming dependent upon other social classes. Hyden's (1980) interpretation of the true objective of relocation schemes such as villagization "is that by placing the peasants in totally new surroundings, their local know-how will be invalid and they will consequently be more open to new ideas and methods of production."

It is instructive to speculate on the role of an FSR organization during this volatile period. The desire to break with the status quo in the countryside, which the Tanzanian government emphasized during this and other periods, results from a lack of respect for peasant agriculture that stands in direct conflict with the basic FSR principle that farmer practices are rational and valuable. It is perhaps as a result of this belief and the establishment of the farm family as the basic unit of analysis for FSR that so little consideration has been given to the problems and opportunities of communal agriculture within FSR. It thus seems likely that during the ujamaa period, an FSR unit would have acted as a conservative force by pointing out the disadvantages and potential problems of instituting the new system and by seeking to disprove the underlying assumption that farmers' resistance to these changes was primarily due to ignorance or apathy.

The villagization period focused more on spatial than on organizational issues. Although on the surface the idea of starting afresh in a new location appears to be closely related to new farming systems development (NFSD), important distinctions should be noted. Tanzanian planners moved the rural population into villages in order to more effectively provide social services and more easily monitor and control their activities. The planners assumed that improved agricultural systems were available and could easily be introduced. This differs in two respects from NFSD. First, scientists engaged in NFSD have focused on the ex ante technical challenges of developing new systems in order to bring new lands, such as valley bottoms, under cultivation. Second, NFSD has been applied with respect to the development of specific farming systems and not in the broad and general fashion of the villagization program. One would therefore expect personnel with an FSR orientation to have strongly opposed the scope and speed of the massive relocation effort that was carried out under the villagization program

and at a minimum to have argued for an incremental approach that would have permitted some initial technical assistance for the newly settled farm families. At each step along the way one would expect the FSR practitioners to have sought to convince the policymakers to explicitly weigh the gains in social services against the losses in agricultural production.

1974-1983: Centralization and Extraction of Surplus

During this 10-year period, the Tanzanian government enacted broad and systemic changes in the agricultural marketing system and foreign exchange policy that altered the relative returns to export and food crops and changed the beneficiaries of the returns. In addition, changes in the central administrative system for village, district and regional areas had the effect of centralizing rural-development decision-making power.

Although the prices of export crops and some staple food crops passing through official marketing channels have been controlled since before independence, during the 1970s new crops were added to the controlled list (sorghum, millets, cassava and legumes). Real declines in producer prices for all crops occurred during the period between the 1967 Arusha Declaration and 1974. Disastrous harvests in 1974 and 1975 raised the specter of food shortages and reversed the direction of this trend for food crops, especially drought-resistant crops. During 1974 through 1979, a weighted index of nominal prices for food-crops increased by 188% while export crops increased by only 98% (Ellis, 1984a). The result was a 21.2% decline in the volume of marketed export crops over the decade and a 25.4% increase in the marketing of staple grains through official channels. Ellis (1984a) points out that the "sensitivity of Tanzanian peasants to changes in the relative producer prices of alternative crops...appears to have been consistently underestimated by policymakers, leading to miscalculations in the priorities signaled to peasants via the price policy procedure."

In addition to changes in prices, changes in marketing structure were instituted that had important effects. Prior to 1976, cooperatives at regional and subregional levels purchased crops from farmer-members and sold them to parastatal organizations. The government feared that the domination of the cooperatives by the richer, more powerful members would result in increasing social differentiation in rural areas. Therefore, in 1976 the cooperatives were replaced by crop-specific marketing parastatals.

Tanzanian farmers have been dismayed by the performance of these parastatals. "Especially in the case of the export crops, the level and growth of marketing costs has imposed increasingly severe constraints on the potential for upward adjustments of producer prices" observed Ellis (1984a). Kleemeier (1984) concluded that since "...the producer share in total product sales value declined to 42% in 1980 from 66% in 1970...the government policy served to extract a surplus from agriculture in order to finance the expansion of the state sector and industry." It is significant to note that although this decrease in the producer share amounted to a 38% tax on agricultural producers, in

relative terms the rural and urban sectors of the economy were squeezed equally by the government (Ellis, 1984b).

The central government's desire for increased control was not limited to economic institutions. The abolition of district councils in 1972 replaced "organizations accountable to the local community through direct popular elections" with "institutions accountable to the centre" (Kleemeier, 1984) in the same way that parastatals had replaced cooperatives in agricultural marketing.

These simultaneous movements in different areas had the common effect of increasing the role and power of the central government. Smallholder agriculture shouldered the burden of this expanded government through increased taxes. By the end of the 1970s some 400 parastatal institutions had been created, many of which operated under huge deficits financed through overdrafts from the banks and government subventions. More prices, both producer and consumer, were controlled, and the practice of blocking the flow of food between the uncontrolled parallel markets in different regions was initiated in order to force farmers to sell through official channels. Through these measures the government displayed decreasing confidence in both the rationality of farmers and the desirability of relying on market allocation mechanisms. The objectives revealed by these policy actions included increased government control over economic and political institutions and the reallocation of resources from the private to the public sector.

The potential role of FSR practitioners can be discussed for each of these policy initiatives. The elimination of the cooperatives should be viewed at least partially as a tradeoff between equality and efficiency. As emphasized in an earlier section, because FSR practitioners have not traditionally focused on equity issues, their tendency may have been to argue for maintaining the cooperative system that was functioning relatively well. It should be noted that former-president Nyerere has subsequently asserted that the elimination of the cooperatives was one of the most serious mistakes he made (Nyerere, 1984).

The overall price-policy initiatives during the period reflected a desire by the government to increase the rate of surplus extraction. Even though this policy had a disincentive effect on producers that was underestimated at the time, it can still be argued that it represented a socially desirable path based on the assumption that the government would make better use of the funds generated. The question of whether the net amount of total government receipts increases or decreases as a function of a change in the percentage remitted to farmers is an empirical one and will depend upon the supply response of the farmers to the new situation. As with the Laffer Curve in the United States, which traces the interaction between the tax rate and the total amount of taxes collected, it is quite possible for the net amount collected by the government to fall as the government seeks to retain a higher percentage of sales. Payer (1983) argues that because Tanzanian farmers have maintained control over their subsistence production, they can elect to withdraw from market activities.

The institution of panterritorial pricing also reflected a movement towards emphasizing equality over efficiency since in strict economic terms, such a system does not provide the signals to producers who will maximize production. Finally, the centralization of control, which was the overriding trend during the period, served to distance decision-making from the people. This directly conflicts with the strong preference within the FSR approach to maintain as much decision-making as possible at the household and local levels.

The 1980s: Crisis Management and Rehabilitation

The last several years have been marked by a recognition of the severity of Tanzania's economic problems and a wide-ranging debate about their causes and potential solutions. The Agricultural Policy of 1982 (United Republic of Tanzania, 1982), the Structural Adjustment Program of 1983, annual budget speeches of 1984 and 1986 and published interviews with Nyerere reveal many of the details of the debate. Shortly after the 1985 presidential election in which Ali Hassan Mwinyi succeeded Nyerere, Tanzania appeared to signal a major change in policy by signing an agreement with the International Monetary Fund (IMF) after 4 years of inaction. The recent Zambian decision to break with a 4-year-old IMF program in that country, however, calls into question the long-term significance of Tanzania's IMF accord (Alagiah, 1987).

Major policy initiatives that have taken place include the reestablishment of cooperatives and reduction of the role of agricultural marketing parastatals, significant price increases for export crops and the elimination of the subsidy price for government-marketed grains, decreases in the number of commodities for which producer and consumer prices are controlled, relaxation of import/export restrictions and devaluation of the currency to levels more nearly approaching its market value. In an effort to reduce government expenditures, some parastatals have been eliminated, combined and reorganized, and an attempt has been made to reduce the number of public employees.

Still, the extent to which state involvement in the country's economic life will decrease is difficult to ascertain since no clear commitment to a change in the overall ideology of state control has been articulated. The current phase may represent an attempt to maintain donor financing by acceding to external demands for reform rather than a fundamental reduction of the role of government in the economy.

In any event, the current era is in many ways a more comfortable one for the FSR approach in Tanzania. Although the government continues to exhort the rural population on a daily basis to do everything from adopting "improved" farming practices to reducing their choosiness with respect to staple foods, it is apparent that the policymakers are displaying a growing acceptance of the wisdom and rationality of farmers and now recognize them as the most efficient producers in the country. As a result, the government has shown an interest in the collection of qualitative and quantitative data that can assist in determining farmer reactions to infrastructure investments and policy actions. In marked contrast to earlier periods, there is a renewed reliance on the

improvement approach to rural development and the use of incentives such as higher prices and increased availability of consumer goods in order to achieve short-term production increases. In sum, the Tanzanian government's decision to rely increasingly on the carrot rather than the stick or exhortation in its dealings with farmers meshes closely with the philosophy of the FSR approach.

FSR PROJECT EXPERIENCES

Even in this more friendly era, conflicts between the FSR program and national policy objectives may still surface. For example, some government policymakers are concerned that the net effect of the consumption-oriented rural policies will be to reduce the rate of surplus (and foreign exchange) accumulation and hence productive investment. FSR teams must therefore maintain an understanding of the government's reliance on the farm population for financial resources in addition to their understanding of the value of incentives at the household level.

A significant example of using the FSR approach to deal with an issue of substantial farmer and national concern was undertaken during the pilot Tanzanian Farming Systems Project in the examination of the role of the cash crop, cotton, in the farming systems of Kilosa District. Throughout much of the district, farm families are required to grow a minimum acreage of sole-cropped cotton in block farms during the long rains (the stick approach). The government requires the foreign exchange from this crop to support its activities. Microeconomic studies carried out in the district have consistently shown that the returns per unit of labor for cotton production are substantially below those obtainable from other crops (summarized in Lev, 1986). These same studies commented on the farmers' half-hearted cotton-production efforts. It appeared that the government and the farmers were frustrating each other since the government was not achieving the level of export earnings it sought while the farmers were having resources diverted from preferred uses.

Our own research revealed significant variations in yield performance and farmer attitudes towards cotton within the district. In the northern zone where the short rains are unreliable, the cotton crop competes directly with food crops for labor, management and land. In this zone, more than 80% of the farmers indicated that they would cease growing the crop if they were free to do so. In contrast, in the southern and central zones, the farmers were able to rely on the short rains for growing subsistence crops. While these farmers complained of some conflicts between cotton and subsistence crops in the period of overlap between the two growing seasons, more than 80% of these farmers indicated that they would choose to continue growing cotton whether or not they were obligated to do so.

In the southern and central areas, the development of a shorter-maturity but lower-yielding maize variety has opened up improved possibilities for the existing but officially discouraged farming practices of relay-cropping cotton after maize. The new maize variety can be harvested a

full month earlier, thereby reducing hunger stress and also reducing competition with the cotton crop. The resulting new system, which was developed and tested by the FSR team, represents a compromise that satisfies the objectives of both local farmers and the national government. It is an excellent example of an FSR team meeting both micro and macro needs (Lev, 1986).

No such mutually acceptable solution was found for the farmers in the northern zone. In that zone either the cotton acreage requirement will have to be waived or farmer subsistence production will continue to suffer as a result of the government regulations.

A second example of a potential conflict between farmers and policymakers is in the area of environmental considerations. Cases have arisen in Tanzania in which farmers have focused on short-term production objectives to the apparent neglect of longer term consequences such as environmental degradation caused by soil erosion or other factors.

While in some instances we noted this situation occurring with our cooperating farmers, we also discovered that many of the mandated "improvements" in resource conservation have not been adequately tested. Although the government is conducting a vigorous campaign to spread the use of green-manure crops (see, for example, the Daily News, June 6, 1985), FSR experiments in specific districts did not demonstrate any economic advantage for one of the proposed systems. In our experiments, the modest yield increases that were realized for the grain crops that followed the green-manure crop did not offset the sum of the opportunity costs for the land and labor required for the green-manure crop. Such examples contribute to an FSR approach characterized by more moderate, localized interventions rather than the blanket, quick-fix campaigns that remain prevalent in Tanzania.

Another issue that is of considerable interest in Tanzania, and which the FSR team examined, is the question of farmer and government attitudes towards the bearing of risk. Although virtually all studies of small-scale farmer behavior have concluded that such farmers are either risk averse or risk neutral in their farming practices, the government's view in Tanzania is that many farmers in drought-prone regions in the country are taking unwarranted production risks by seeking to grow inappropriate crops (such as maize instead of sorghum). The government is not a disinterested observer; government officials recognize that they function as the insurer of the last resort in cases of severe crop failure.

One explanation of this surprising example of risk-preferring farmers is that while the farmers evaluate the maize/sorghum tradeoff in terms of their internal preference evaluation of the two goods, the government values the two crops at the supply prices that it faces. As a result of these two different price ratios, it is possible for the same behavior to be viewed as risk neutral or averse from the farmer's perspective while it appears to be risk preferring from the government's perspective. A second and related explanation is that the farmers recognize and depend on the existence of a government safety net.

The decisions regarding which and how many farmers to work, with represents a final potential area of conflict. Since locally based FSR teams generally do not have a broad enough perspective to select appropriate groups of farmers, it is proper for the national government to have a major role in this decision. On the positive side, this will assist in selecting target groups and will reduce the possibility of the FSR teams being "captured" by the local elites. On the negative side, the FSR section in Tanzania felt pressure from above to expand their effort more quickly and broadly than they felt capable of accomplishing.

In Tanzania an important issue that must be confronted as one initiates an FSR program is the class of fields that will be examined. While Tanzania's ambitious experiment with communal agriculture has had little effect on the organization of production within the country, vestiges of the experiment remain in the form of the village or collective farms. Should the FSR teams make a special effort to work with these group enterprises, or should they instead take the easier path of working with and designing technologies for the more productive family farms? Either choice makes a political statement. Our pilot FSR project took the easier road of working with individual families.

SUMMARY AND CONCLUSIONS

Although the initial burst of enthusiasm for the FSR approach has faded, many FSR practitioners believe that it will continue to influence agricultural research and extension activities in developing countries. A series of critiques have been published recently that point out shortcomings of the standard FSR approach and suggest methods of overcoming these difficulties. This paper focused on one of these neglected areas as it considered the nature and range of interactions between FSR practitioners and national policymakers. Although it may be argued that one of the fundamental reasons for the development of the FSR approach was the desire to provide greater voice to farmer interests and concerns, FSR teams must also maintain an appreciation and understanding of national interests and objectives. FSR practitioners should not, however, be asked to generate support for government policies because this would undermine their credibility and effectiveness with their clientele group.

It has been demonstrated through this historical review of Tanzanian agricultural policies that the FSR approach may either support or subvert the attainment of specific policy goals. The FSR approach is supportive of production-oriented goals that are based upon motivating farmers through the provision of appropriate infrastructure and incentives. Information derived from FSR activities and provided to policymakers can assist in increasing total production, governmental surplus and foreign exchange receipts. In order to perform this role effectively, the FSR teams must be properly trained to accurately collect and transmit relevant field-level information upward (an FSIP function) and to appropriately translate government priorities down to the local level.

Whether or not the FSR approach lends support to government policies that focus on distributional issues is unclear. The approach sets up as its objective function the maximization of individual family welfare for specified groups of families. This may or may not assist the government in achieving its distributional and equity objectives, since in the postintervention phase the distribution of incomes (or welfare) may be either more or less in line with governmental objectives.

The FSR approach, because of its focus on step-by-step changes and the maximization of individual welfare, would appear to be less supportive, and might in some instances even subvert government policies that seek, a dramatic transformation of the agricultural sector. Although the new farming system development (NFSD) approach provides some guidance on the technical aspects of such a transformation, the farming systems perspective provides little direction in terms of the long-term structural and social aspects of such a transformation.

The overall goal of this paper is to facilitate improved communication between FSR personnel and national policymakers. The communication must be in both directions. The FSR teams can provide new insights, which will aid in the formulation of improved policies. The national policy goals that are handed down will provide the FSR teams with another basis to judge and modify potential technological interventions. The long-term success of any FSR program depends upon whether it effectively fulfills both of these roles.

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HOW GOVERNMENT FARM PROGRAMS DISCOURAGE SUSTAINABLE CROPPING SYSTEMS: A U.S. CASE STUDY

Douglas L. Young and Walter A. Goldstein[1]

INTRODUCTION

Concern about resource depletion, agrichemical pollution and recent severe financial stress in grain-growing regions has renewed interest in sustainable, low-input, low-cost farming systems in the United States. Organic, alternative and regenerative agriculture are terms that have been used to describe low-input farming systems.

The benefits of low-input farming systems have been frequently enumerated. Papendick et al. (1986) have discussed how low-input systems can save soil, abate agrichemical pollution and enhance wildlife habitat. Substitution of forage legumes or other green manures into crop rotations as natural nitrogen sources reduces the potential for nitrate pollution, protects the soil and can decrease the need for pesticides by disrupting disease and weed cycles that flourish in cereal-intensive rotations. Among important social benefits of sustainable low-input farming systems are fewer pesticide residues in the food supply (Clancy, 1986). From a longer term social perspective, these systems conserve energy, topsoil and wildlife for future generations. Among frequently cited economic advantages of a transition to organic farming systems are the reduction of commodity surpluses, lower taxpayer costs for farm programs and possibly higher market prices as farmers reduce cereal production.

Several studies have been completed that show that organic farms can be as profitable as or more profitable than their conventional counterparts in certain situations. Hodges (1978) and Cacek and Langner (1986) summarize several studies showing favorable economic performance of organic farms in the United States. Vogtmann (1984) cites similar results for organic farms in Europe. Such studies notwithstanding, the vast majority of U.S. farms continue to use conventional practices that rely heavily upon agrichemical inputs. An essentially negligible proportion of total U.S. food and fiber is produced by genuinely organic methods. Considering the claims in the sustainable-agriculture literature of multiple advantages of low-input agriculture and its profitability in case-study comparisons, a reader might legitimately wonder why low-input systems are not more common in the United States. A major hypothesis of this paper is that the answer is related to the nature of U.S. farm-commodity programs.

Our specific objectives are to:

[1]Professor of Agricultural Economics at Washington State University, Pullman, Washington, U.S.A.; Research Agronomist at Michael Fields Agricultural Research Institute, East Troy, Wisconsin, U.S.A.

- discuss the mechanisms by which U.S. farm-commodity programs encourage conventional farming systems and discourage low-input systems

- examine the comparative economics of a conventional and a low-input farming system in the Palouse region of southeastern Washington State with particular attention to the role of commodity programs

- examine distributional, environmental and long-term international competitive implications of a phaseout of U.S. commodity programs

- assess the likely direction of future U.S. farm-commodity programs and the implications for sustainable agriculture

HOW U.S. COMMODITY PROGRAMS ENCOURAGE CONVENTIONAL AGRICULTURE

United States commodity programs encourage intensive production of selected crops with high levels of agrichemical inputs through two principal mechanisms. The first is by restricting program payments to only certain agricultural products. The second is by making payments for many commodities proportional to historical production of the commodity. Of the $155-billion gross market value of crop and livestock products produced in the United States during 1985, only about one-half were included in commodity programs (USDA, 1986). Corn and other feed grains, wheat, cotton, soybeans, rice, tobacco and dairy products account for the lion's share of government farm subsidies. A study cited in Newsweek (1987), which was based on the USDA data, estimated that 47% of 1986 farm subsidies went to corn and other feed grains, 13% to wheat, 9% to cotton, 6% to soybeans, 4% to rice, 1% to tobacco, 8% to dairy and 12% to all other supported commodities. Many farmers and ranchers never deposit a government subsidy check. Growers outside the government circle include beef and sheep ranchers, hog growers, hay growers, egg and broiler growers, vegetable producers and fruit orchardists, among others. Of course, government farm programs indirectly affect even producers of nonsupported commodities through market interactions. For example, feed-grain price supports reduce feed costs for livestock feeders.

It is longstanding conventional wisdom among agricultural economists that the selective largess of U.S. commodity programs directs resources away from nonsupported commodities and toward supported commodities. Land that might be used to produce vegetables is used for tobacco or cotton instead. Wheat or barley that might be produced in rotation with forage legumes is produced in intensive rotations supported by high fertilizer and pesticide applications. Land that might otherwise be producing hay and sheep is used for dairying, and so on.

Government payments to grain growers, and by means of varying mechanisms to most commodity program participants, are tied to historical production levels. Grain growers receive a "deficiency payment" per bushel multiplied by their historical or "established" yield for the crop over the number of historical or "base" acres in that crop, net of any set-aside acreage. The deficiency payment per bushel is equal to

the difference between the legislated target price and the loan rate or average market price, whichever is higher. The individual farmer has no control over the legislatively market-determined deficiency payment per bushel, but historically the farmer has had considerable control in the long term over his established yield and base acreage. Increases in deficiency payments by expanding base acreage and established yields are long term — the endure as long as the farm-commodity programs persist. Also, these increases in farm income are largely immune to short-term fluctuations in weather and market prices. If a drought cuts a farmer's yields in half, the deficiency payments for that year that are based upon historical yields are not affected.

Consequently, given the coupling of government farm subsidies with production levels of supported crops, there is a strong incentive for farmers to push the intensity of supported crops in rotations toward their biological limits. Similarly, there has been strong incentive to fertilize and apply pesticides for near-maximum yields. The latter incentive was largely dampened by the 1985 Farm Bill, which froze farmers' established yields as of 1986.

It should be noted that not all farm-subsidy programs encourage the intensive farming systems described above. Programs that are not coupled to production, such as paid acreage diversion, do not generate the same intensification incentives as do deficiency payments. Long-term land-retirement programs, such as the 1950's "Soil Bank" and the Conservation Reserve Program established by the 1985 Farm Bill, are not linked to production. Such programs are essentially neutral in their impact on low-input systems (compared with conventional production systems) on the land that remains in cultivation.

Some economists and legislators, such as U.S. Senator Boschwitz (1987) from Minnesota, have advocated "decoupling" all U.S. farm subsidies from production. This would permit "targeting" payments to particular types of growers, for example, "family farmers." Decoupling would make commodity programs neutral with respect to the choice between low-input and conventional production systems. Historically, however, American farmers have resisted decoupled direct payments. Such payments smack of welfare and shatter the argument that the subsidies have been "earned."

Theoretical arguments supporting the high-input bias of current U.S. commodity programs are fairly clear. However, whether or not a viable low-input system would be competitive with current conventional systems is likely to vary by region and by commodity. Obviously, some nonsubsidized commodities such as most fruits and vegetables appear to be most profitably produced by chemical-intensive systems, even in the absence of subsidies. The same applies for livestock-feeding operations, which have come under fire for heavy use of chemical implants and antibiotics.

Termination of government farm programs is likely to motivate the greatest shift toward low-input systems in mainstream field-crop agriculture, where the feed-and-food-grain programs of the past have been so influential. To shed some light on the microeconomics of the

role of cereal-support programs, we report a case study from the Palouse region of southeastern Washington.

A PALOUSE CASE STUDY

The Palouse region of southeastern Washington State and adjacent northern Idaho is one of the premier wheat-producing areas of the United States. Wheat and barley are grown in intensive rotations containing 50% to 100% cereals. Favorable climate, soils and high-technology production generate some of the highest dryland wheat yields in the world. In the eastern Palouse, which receives 18 to 22 in. of precipitation per year, wheat yields averaging 80 bu/acre (5,389 kg/ha) are common.

The cereal-intensive cropping systems of the Palouse have been favored by both technical and political trends. Postwar technical breakthroughs providing inexpensive nitrogen fertilizer, effective chemical herbicides and efficient machinery all favored intensive wheat and barley production. During the same period, the availability of generous price and income supports for wheat and barley, but not for edible or forage legumes, further increased the dominance of cereals.

The cereal-intensive farming systems in the Palouse and elsewhere in the nation have brought their own set of problems. From an economic perspective, foremost among these problems has been the periodic accumulation of large grain surpluses, which have depressed world grain prices. Current U.S. stocks of wheat, for example, approach a full year's domestic and foreign demand for U.S. wheat. These surpluses keep market prices low and build pressure to sustain expensive government price-support programs. The emphasis on cereals in the Palouse has also spawned serious environmental problems. The region's exceptionally steep topography, combined with finely tilled seed beds for winter wheat, has led to high rates of soil erosion. Topsoil loss at current levels in the Palouse will limit future land productivity and further degrade water quality in the region. The intensive use of inorganic fertilizers and chemical pesticides to sustain cereal rotations in the region also increases the risk of chemical pollution of waterways and aquifers.

Agricultural researchers have responded with new technology in an attempt to solve some of these problems. For example, no-till farming systems can substantially reduce topsoil erosion. However, no-till systems generally require increased herbicide use for weed control, increasing pesticide runoff. The machinery required for such systems is also expensive, and many farmers have been reluctant to adopt these systems because their capability to sustain yields in all areas has not been confirmed (Young et al., 1984).

In response to the problems described above, it is worthwhile to examine alternative low-chemical, legume-based systems for producing cereals in the Palouse. Until the 1950s and 1960s, when low-cost fertilizer and pesticide inputs were introduced, cereal rotations involving sweet clover and alfalfa were commonly used in the Palouse (Kreizinger and

Law, 1949; Law et al., 1945; Pawson et al., 1961). Livestock were also frequently integrated into these systems to make use of forage grown during the legume portion of the rotation. But livestock numbers in Whitman County have declined sharply as cropping rotations have intensified.

The following analysis examines the economic viability of an experimental, low-input, legume-based rotation compared to a conventional rotation for the eastern Palouse. Special attention is devoted to the influence of wheat and barley programs on the relative profitability of the two rotations. The legume-based rotation, based on recent experimental field research by Goldstein (1986), is referred to by the acronym PALS, Perpetuating Alternative Legume System. PALS is a 3-year rotation with year one in spring peas plus medic, year two in medic alone and year three in winter wheat. The conventional system is a 4-year grain-cropping rotation with year one in winter wheat, year two in spring barley, year three in winter wheat and year four in spring peas. By growing supported cereal crops 75% of the time, compared to only 33% in PALS, the conventional rotation clearly stands to benefit more from current commodity programs.

The medic in PALS was a biennial black medic (*Medicago lupulina* L.) cultivar such as the Danish cultivar (virgo). Medic and peas were planted together during the first year of the PALS rotation, and the peas were harvested in July. In the second year, the biennial medic was allowed to go to seed, and no crop was harvested. Medic residues and seed were lightly disked into the soil in the fall, and winter wheat was seeded, which was harvested the following August. In the fourth year, the medic volunteered back in a seeded crop of spring peas to mark the beginning of another 3-year cycle. Wheat is grown in similar "self-perpetuating" medic rotations in Australia (Puckridge and French, 1983). In some Australian fields, the medic stands have reportedly persisted without reseeding for over 30 years (personal communication, R. I. Papendick, USDA Soil Scientist, Pullman, WA). In this study, medic reseeding is assumed every three cycles, or 9 years.

Australian wheat-medic production systems frequently incorporate sheep during the forage-producing component of the rotation. Neither haying nor grazing of medic is assumed in this Palouse study. Although livestock were once common in the Palouse, neither fences nor water facilities exist on many Palouse farms today. Palouse farmers are fond of pointing out to their Midwestern brethren that when Secretary of Agriculture Earl Butz urged U.S. farmers to plant fencerow to fencerow in the mid-1970s, they did him one better. They tore out the fencerows and farmed them too.

Fertilizer and pesticide use for the conventional system and the PALS is outlined in Table 1. Conventional wheat and barley receive typical applications of nitrogen, phosphate and sulfur. No fertilizer is applied in the PALS rotation. Only peas in the PALS cycle receive pesticides. Herbicide, insecticide and fungicide applications are typical of those found in the region for the conventional rotation. Readers are referred to Goldstein (1986) and Goldstein and Young (1987) for further details on recommended agronomic practices for the systems

and the original presentation of the economic comparison for this case study.

Experimental results for the Palouse region showed that unfertilized winter wheat yields following medic were comparable to fertilized winter wheat yields following cereals (Table 2). Not surprisingly, yields of cereals following cereals are sharply reduced without fertilizer — by an average of 20 bu/acre (1,347 kg/ha) or 50% for the trials in Table 2. In contrast, the data in Table 2 indicate unfertilized winter wheat following medic yields, as well as fertilized winter wheat following cereals in the Palouse. While the research evidence to date is limited, and more work is needed, the evidence in Table 2 is encouraging for the viability of low-input systems in the Palouse. The sharp reduction in unfertilized wheat yields for wheat after cereals helps support the earlier argument that farm programs that base payments on high yields and acreages of cereals will virtually guarantee high levels of purchased input use.

Based on Goldstein's multiyear results, and other research results cited in Table 2, yield levels as specified in Table 3 were assumed for the PALS and conventional management systems. Wheat yields were assumed to be the same for both systems in both high- and low-yielding areas (or years). However, pea yields were slightly lower under PALS due to competition from the medic. Extensive ancillary observations on root growth, weed counts and yield-component analysis indicated that one of the primary contributions to higher yields of cereals following medic was the suppression of cereal-disease cycles (Goldstein, 1986). Consequently, the contribution of legumes in cereal cycles goes beyond simple nitrogen fixation.

Complete enterprise budgets were developed for each of these rotations using 1986 input prices, machinery efficiencies and other budgeting procedures followed by Washington State University extension economists (Goldstein and Young, 1987). The budgets reflected the substantial local decreases in nitrogen prices over 1986 to 19C/lb to 22C/lb compared to 29C/lb a year earlier. Production costs included all variable costs of production including seed, fertilizer, pesticides, custom services, machinery repairs, fuel, lubrication, crop insurance, overhead, interest on operating capital and the farmer's labor. Fixed costs associated with machinery and land were not included because these would be the same under both systems in the short term. In the long term, some reduction in the machinery complement, or slower wearout of an existing machinery complement, might actually lead to lower fixed costs with PALS. Tillage costs closely reflect different cultural practices for individual crops. For example, conventional wheat that followed barley had higher variable tillage costs than did wheat after peas because it cost more to plow barley stubble than to disk pea residue. No budget was prepared for the year of medic in PALS because no operations were performed.

As shown in Table 4, the annual variable costs per acre of rotation for conventional management ($129.40/acre/year) were 128% higher than under PALS ($56.82/acre/year). Costs also differed markedly in composition between the two management systems. In Table 4, variable costs are

partitioned into the cost of chemicals (fertilizers, pesticides and their application), the cost of other field operations and the cost of overhead and crop insurance. For conventional management, agrichemical costs of $72.52/acre/year were 4.8 times higher than were those for PALS ($15/acre/year). The conventional field operation costs also exceeded those for PALS, primarily because of the absence of any operations in the medic year of the PALS rotation. Clearly, chemical inputs dominate variable production costs for modern cereal-intensive rotations in the Palouse, as elsewhere. Again, these results indirectly support the argument that current U.S. commodity programs encourage intensive use of agrichemical inputs. Recent visiting foreign scholars at Washington State University independently expressed to the senior author their surprise at the high cost of wheat production in the Palouse compared to South Australia and Saskatchewan, Canada (personal communications, Albert Rovira, Soil Scientist CSIRO, Adelaide, South Australia, and G. C. van Kooten, Agricultural Economist, University of Saskatchewan). The previously hypothesized linkage between agrichemical use and commodity programs was manifest in their common comment that their farmers, who must survive with farm-gate prices much closer to world market levels, would never be able to afford production costs as high as those in the Palouse.

To examine the influence of current U.S. commodity programs on comparative system profitability, the economic analysis uses both 1986 target and local market prices. The 1986 regional market prices were $70/ton (8¢/kg) for barley, $2.40/bu (9¢/kg) for wheat and $9/cwt (20C/kg) for peas. Corresponding target prices were $108/ton (12¢/kg) for barley and $4.38/bu (16¢/kg) for wheat. There is no target price for peas since they, like all edible and forage legumes except soybeans, are not included in government programs. The relatively large gaps between market and target prices — $1.98/bu (7¢/kg) or over 80% of the market price for wheat and $38/ton (4¢/kg) or over 50% for barley — reflects the depressed market for cereals and relatively generous U.S. target prices that existed in 1986 and that persist today.

Table 5 reports the returns over variable costs for the two systems under both market and target prices. To simplify exposition of the relationship of the net returns in Table 5 to the costs, prices and yields for each system reported earlier, we ignore the costs of set-aside acreage in the target-price scenario. It should be noted that this is a conservative simplification, which puts PALS at a disadvantage. If a grower shifting to PALS has a high historical wheat base, which is likely, part of the acreage in the idle medic year could be used as wheat set-aside. In the conventional rotation, a grower would have to idle cropped ground to comply with set-aside requirements.

Under both price scenarios, the conventional system has considerably higher gross returns than does PALS ($274 versus $171, under high-yield conditions) because crops are harvested every year in the former system (Table 5). The government target prices would markedly increase gross returns for participants in commodity programs of wheat and barley, but especially under the intensive conventional system. Under the high-yield scenario, which is more typical in the eastern Palouse, government wheat and barley programs gave the conventional system a large $33, or

27%, advantage over PALS. This result goes a long way in explaining the virtual monopoly of conventional farming practices in the Palouse.

Removing government payments for wheat and barley reverses the results. Under 1986 market prices, and both yield assumptions, PALS generated higher net returns than did conventional management. With market prices, under low- and high-yield conditions, PALS earned $73.09/ha/year and $36.04/ha/year more, respectively, than did conventional management. With target prices and under high-yield conditions, conventional management produced $76.10/ha/year more net returns than did PALS. Under low-yield conditions, there was little difference in net returns between conventional and PALS management ($81.20 and $75.79, respectively).

It is well to emphasize that even with the availability of a viable low-input PALS to cushion the economic blow caused by withdrawing wheat and barley subsidies, the reduction in returns to fixed factors is severe. In the high- and low-yield areas, respectively, returns with conventional and target prices compared to PALS at market prices differ by $83 (-57%) and $45 (-55%). While U.S. supply reductions in response to terminating U.S. commodity programs would eventually bolster wheat prices somewhat above the depressed 1986 market level, it is likely that the resulting economic stress could push land prices below current depressed levels, and some farmers could be forced out of business.

Table 6 displays the influence of changes in wheat price, all other prices held at assumed market levels, on the profitability of the two systems. Under the high-yield conditions, conventional and PALS management had the same returns when the price of wheat was $3.50/bu (13¢/kg); above that price the conventional system was more profitable, and below that price it was less profitable. The "break-even" price of $3.50/bu is considerably above the 1986 market price of $2.40/bu (9C/kg) but well short of the 1984-1987 target price of $4.38 and the 1988 target of $4.29. Under the low-yield conditions, conventional and PALS management had the same returns when the price of wheat was $5.36/bu (20¢/kg); above that price the conventional system was more profitable, and below that price it was less profitable.

Before proceeding it is important to acknowledge the limitations of the partial-equilibrium budgeting analysis just discussed. It abstracts from the multiple adjustments in input and output markets that would be set in motion by terminating cereal price supports. Supply cutbacks by U.S. farmers would likely increase world market wheat and barley prices after U.S. commodity programs were terminated. The concurrent rise in grain prices would alter the analysis in Table 6, which assumes a stable barley price as wheat price adjusts. Furthermore, decreasing U.S. grain acreage and a shift to legume-cereal rotations could impose significant reductions in the demand for and price of nitrogen fertilizer and other inputs. These adjustments are not considered.

Notwithstanding its limitations, the preceding analysis clearly indicates that a pattern of lower cereal prices, similar to current world-market wheat and barley prices, favors return to a less intensive,

legume-based system such as PALS. The analysis indicates that the current cereal-intensive rotation in the Palouse is supported in large part by government farm programs that favor grains.

Finally, PALS is still an experimental system in the Palouse. Although such systems seem to hold considerable agronomic and economic promise, further research is needed to establish their long-term viability in this region.

Having examined in detail the economic prospects for a specific sustainable system in one region, we turn in the next section to a more speculative assessment of the aggregate and long-term economic implications of a termination of government programs.

AGGREGATE ECONOMIC EFFECTS OF ENDING FARM PROGRAMS

The potential long-term social and environmental benefits of a transition to more sustainable farming systems in the United States are widely recognized. There is less agreement that the adjustment costs of terminating farm subsidies, which might be necessary to achieve this transition, are worth the long-term payoff. American farmers and supporting agribusiness industries have become deeply wedded to government payments.

Farm-sector Adjustments

Despite the economic-efficiency argument for terminating government farm subsidies, most agricultural economists resist the idea and instead focus their attention on the substantial adjustment costs such termination would impose upon the farm sector. A recent "agriculture's futures" study by a wide cross-section of agricultural policy specialists concluded the following (Wallace, 1987):

> Highly leveraged farms would stand virtually no chance of remaining solvent for the next 10 years in the absence of farm programs. Because one-third of U.S. farmers are considered to be highly leveraged, even a transition policy to phase out farm price and income support would likely cause rapidly falling land values, accelerated structural change and added stress on the agricultural financial sector. The brunt of such adverse conditions would be directly felt by rural lending institutions. In fact, the solvency of the rural credit system could be seriously threatened if asset values continued to decline from their current, relatively low level. Almost complete curtailment of private sector credit to moderately and highly leveraged farmers could be anticipated.

Producers of nonsupported agricultural outputs would also be affected as some grain growers, rice growers, dairymen and other supported-commodity producers shifted to traditionally nonsupported commodities after the termination of subsidies. In addition to the adjustments mentioned by Wallace, agrichemical and machinery suppliers would likely face sharp reductions in demand as U.S. agricultural output shrinks and production

practices change after terminating farm subsidies. Employment and income in these agribusiness sectors would fall accordingly.

Ultimately, of course, farm-sector adjustments will appear as reductions in the value of agriculture's principal fixed factor, namely land.

Although short-term adjustments are likely to be painful, the long-term prognosis from terminating or altering farm programs may be considerably more optimistic. We turn to an assessment of long-term impacts in the next section.

Long-term Social Benefits

As previously noted, there has been relatively little discussion of the general efficiency gains from terminating farm programs and of ways these liberated resources might be spent to enhance welfare. The discussion of using resources from current farm programs to support targeted and decoupled payments to certain groups of farmers is an exception. There is also little discussion in the standard policy debate of the long-term resource-conservation and environmental benefits that might flow from terminating or decoupling federal farm subsidies. In this section we briefly review some of the potential long-term social benefits of a farm policy that terminated or decoupled federal subsidies for selected commodities. We recognize that these diffused benefits are speculative and difficult to measure. However, they are too important to overlook, in a serious policy analysis.

First, currently high target prices for selected commodities motivate use of energy, topsoil, groundwater and other resources beyond the economically optimal rates indicated by market prices. The major beneficiaries of resource conservation are future generations. How large are the benefits of reduced rates of resource depletion and pollution? A nearer-term, but geographically further-removed, set of potential benefits of terminating U.S. farm subsidies would be the positive impact on incentives for self-sufficiency in less developed countries. Low world food prices, free or inexpensive food aid and protectionist policies against LDC export crops (e.g., sugar) all discourage self-sufficiency and agricultural development in struggling LDCs (Schuh, 1986). Schuh has argued that in the long term, promoting agricultural development in LDCs promotes the economic interest of the United States and other developed countries. The long-term capacity of these countries to trade with the United States for mutual gains is based upon effective demand, not need.

A difficult-to-quantify but very important impact of farm subsidies is their influence on the long-term competitive position of U.S. agriculture in international trade. There is increasing empirical evidence that the United States no longer enjoys a competitive cost advantage over its major competitors (Doane's Agriculture Report, 1986; Ortmann et al., 1986). Quoting from a recent U.S. Office of Technology Assessment Study, Doane's Agricultural Report (1986) stated:

> OTA says the U.S. doesn't enjoy a large cost advantage over its major competitors in several key world markets. And some of our

> farmers, particularly in less efficient production areas, are operating at costs well above world prices. These farmers remain competitive only because of domestic price support policies.

The same report stated that a Chase Econometrics cost study showed Argentina to have lower production costs than the United States for corn, wheat and soybeans, and Canada to have lower wheat-production costs. Ortmann et al. (1986) found that Argentine and Brazilian soybean producers were more efficient than their U.S. counterparts, as were Argentine, Australian and South African wheat producers and Thai and Argentine corn producers. However, U.S. producers were generally more efficient than those in Europe who, incidentally, receive higher subsidies.

Some analysts (Wallace, 1987) are pessimistic about whether terminating U.S. farm programs can improve our international agricultural trade position. However, it is difficult to theorize how a continuation of the current protected position could improve the long-term competitive position of U.S. producers. As U.S. producers remain insulated from market forces, the gap between U.S. production costs and world market levels that must be picked up by taxpayers could grow beyond acceptable levels.

The preceding scenario describes the recent experience of New Zealand, which reinstituted a free-market policy after the costs of subsidies and grants become too onerous to bear (Dickinson, 1987). Dickinson reported that while short-term adjustments have been difficult, the long-term future of New Zealand agriculture under the new policy is promising. Also, exit by New Zealand farmers has been less than expected under the new market-oriented policy. Some of the countries that are providing U.S. farmers their toughest competition, such as Australia and Argentina, have reduced production costs by producing grains in low-input livestock-forage-grain rotations, which make very low use of fertilizer and other agrichemical inputs (Ortmann et al., 1986; personal communication, Albert Rovira, 1987).

PROSPECTS FOR CHANGE

It is the judgment of the authors, based on empirical observation and economic theory, that no major transition to sustainable agriculture will occur in the United States until 1) the current policy of subsidies to selected commodities ends or 2) the policy is reformed to decouple subsidies from production.

What are the prospects for major reform or termination of U.S. farm policies within the next decade? While there has been little action, there have been widespread proclamations of support for terminating U.S. farm programs. On July 6, 1987, the Reagan administration proposed at a meeting in Geneva, Switzerland, of the 93-country General Agreement on Tariffs and Trade that all farm subsidies in the world be terminated as part of a multilateral program by the turn of the century. There has been no rush by other countries with major agricultural support programs, most notably the EEC, to endorse this proposal. However, the

proposal legitimizes termination as a serious option for public debate. Willard Cochrane (1986), an eminent agricultural economist and long-time architect of government farm programs, has also added his support for their immediate termination. There are increasing reports in the popular press of farmers themselves who wish to get "off the public dole" (Newsweek, 1987). In part, this grassroots sentiment seems to be founded in a belief that the long-term competitive strength of U.S. agriculture would be served by foregoing subsidies:

> In the midwest it is now coffee-shop gospel that, despite 50 years of government assistance, farmers producing subsidized commodities lag behind livestock raisers, vegetable growers, and others who fend for themselves in the market place (Newsweek, 1987).

However, farmers proposing to eliminate farm programs are probably still a fairly small minority. Even those who speak out against farm programs presumably keep their federal checks, and, if pushed, would probably condition their preference for a free market by requiring other governments to play by similar rules.

In spite of the active debate and varied sources of support for agricultural policy reform, there is little chance of change in the current Congress (Webster, 1987). Over the long term, however, we believe that change is inevitable because of 1) the growing contribution of agricultural subsidies to the already politically unacceptable federal deficit and 2) growing world supplies of basic commodities due to possible breakthroughs in biotechnology and improving competitive strength overseas. These factors reduce the likelihood of a bailout through a price-improving demand-supply balance (Harl, 1987; Wallace, 1987). It is likely that lower future U.S. income and price supports for grains, cotton, tobacco and other resource-depleting crops will improve incentives to grow these crops in low-input, sustainable systems of the type that are already used by farmers in Australia, Argentina, and elsewhere.

If our prognosis is correct, an important policy implication for USDA and the land-grant universities is to accelerate research now on technically sound, low-input, low-cost farming systems adapted to different crops and regions. Driven by the strong subsidies for grains, cotton and other supported commodities, much postwar U.S. agricultural research has emphasized high yields in response to agrichemical inputs of crops grown in intensive rotations. Unfortunately, American farmers may not be able to afford the products of this research in the future. The need for low-input systems will be made doubly urgent if energy prices escalate again as subsidies are phased out. Fortunately, considerable good research on low-input systems was done in the United States prior to the inorganic-nitrogen revolution (e.g., Law et al., 1945; Pawson et al., 1961) and continues to be done overseas (e.g., Puckridge and French, 1983). These knowledge banks can be tapped.

As we move away from the current system of payments tied to selected commodities, a major debate will focus on what should take their place. We argue that the social and community benefits of preserving a sizeable, rural, farming population justify targeting payments,

decoupled from production, to prevent wide-scale forced exit by moderate-scale farmers. Supporters of sustainable agriculture should realize that a low-input agriculture need not necessarily be a small-scale, family-oriented agriculture. If family-farm agriculture is accepted as a social goal, public intervention using decoupled subsidies may be necessary to preserve it.

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Table 1. Assumptions for fertilizer and pesticide use for conventional management and PALS.

Crop	Fertilizer N (lb/A)	Fertilizer P (lb/A)	Fertilizer S (lb/A)	Pesticides: Herbicide (trade name)	Pesticides: Rate (units/a)	Pesticides: Insecticides or fungicide (trade name)	Pesticides: Rate (units/a)
Conventional:							
winter wheat	130	30	25	Avenge	3.0 pt	Benlate	1.5 lb
				Bronate	1.4 pt		
spring barley	80	0	0	Fargo	1.25 qt		
				Bronate	1.5 pt		
winter wheat	130	30	25	Avenge	3.0 qt	Benlate	1.5 lb
				Bronate	1.5 pt		
spring peas	0	0	0	Fargo	1.25 qt	Imidan	1.5 lb
				Dinoseb-Amine[a]	0.8 lb		
PALS:							
peas + medic	0	0	0	Fargo	1.25 qt	Imidan	1.5 lb
				Dinoseb-Amine[a]	0.8 lb		
medic	0	0	0	0	0	0	0
winter wheat	0	0	0	0	0	0	0

[a]Registration of Dinoseb-Amine was suspended in 1987.

Note: 1 lb/acre equals approximately 1.12 kg/ha.
1 pt/acre equals approximately 1.16 liters/ha.
1 qt/acre equals approximately 2.35 liters/ha.

Table 2. Results from field trials comparing the yields of unfertilized cereals following cereals, fertilized cereals following cereals, or unfertilized cereals following medic, eastern Washington.

Following crop	Location	Harvest year	Preceding crop: Cereals, Unfertilized	Preceding crop: Cereals, Fertilized	Preceding crop: 1 year medic, Unfertilized	Preceding crop: 2 years medic, Unfertilized
			bushels/acre			
Winter wheat	Pullman	1984	36.5	62.1[a]	64.9	--
Winter wheat	Pullman	1985	19.5	21.3[b]	--	38.1
Winter wheat	Pullman	1984	55.0	86.3[c]	77.4	--
Winter wheat	Dusty	1984	49.0	71.4[d]	70.0	--
Spring wheat	Davenport	1984	14.3	19.4[e]	--	19.5
Spring barley	Pullman	1985	--	34.0[f]	--	63.1
Average for winter wheat			40.1	60.3	62.6[g]	

[a]Winter wheat followed spring barley and was fertilized with 150 lb of N per acre (Goldstein, 1986).
[b]Winter wheat followed winter wheat and was fertilized with 100 lb of N per acre (Goldstein, 1986).
[c]Winter wheat followed spring barley and was fertilized with 80 lb of N per acre (personal communication, Elizabeth Kirby, Washington State Univ., Department of Agronomy and Soils).
[d]Winter wheat followed spring barley and was fertilized with 50 lb of N per acre (personal communication, Elizabeth Kirby, Washington State Univ., Department of Agronomy and Soils).
[e]Spring wheat followed winter wheat and was fertilized with 120 lb of N per acre (Goldstein, unpublished data).
[f]Spring barley followed winter wheat and was fertilized with 80 lb of N per acre (Goldstein, unpublished data).
[g]The yields of winter wheat after medic were averages for wheat following 1 and 2 years of medic.

Table 3. Yield assumptions for crops grown under conventional management and PALS.

Crop	Yield units	Conventional High yield	Conventional Low yield	PALS High yield	PALS Low yield
		.....per acre			
Wheat	bushels	80	60	80	60
Barley	tons	2	1.6		
Peas	pounds	2,000	1,600	1,800	1,500

Note: 1 bushel per acre equals approximately 676 kg/ha.
1 ton per acre equals approximately 2245/kg/ha.
1 pound per acre equals approximately 1.1kg/ha.

Table 4. Composition of average annual variable costs for conventional management and PALS.

Cost category/system	Costs ($/acre)	Percentage of system total
Fertilizers and pesticides (application and product)		
conventional	72.52	56.0
PALS	15.00	26.4
Field operations (tillage, planting, and harvesting)		
conventional	45.44	35.1
PALS	35.00	61.6
Overhead and crop insurance		
conventional	11.44	8.9
PALS	6.82	12.0
Total		
conventional	129.40	100.0
PALS	56.82	100.0

Table 5. Gross returns, variable costs, and net returns for conventional management and PALS under high- and low-yield conditions and under market and target prices in 1986.

Yield level/system	1986 market prices Gross returns	1986 market prices Variable costs	1986 market prices Net returns	1986 government target prices Gross returns	1986 government target prices Variable costs	1986 government target prices Net returns
	-Average annual $/acre-					
High yield						
conventional	176.00	129.40	46.60	274.20	129.40	144.80
PALS	118.00	56.82	61.18	170.80	56.82	113.98
Low yield						
conventional	136.00	129.40	6.60	210.60	129.40	81.20
PALS	93.00	56.82	36.18	132.60	56.82	75.78

Table 6. Effect of wheat prices on net returns for conventional and PALS management systems under high- and low-yield conditions when barley and pea prices are set at market prices.

Price of wheat	Conventional High yield	Conventional Low yield	PALS High yield	PALS Low yield
	..... returns in $/acre/year			
$5.36	165.00	95.40	140.13	95.40
$5.00	150.60	84.60	130.53	88.18
$4.00	110.60	54.60	103.86	68.18
$3.50	90.60	39.60	90.60	58.18
$3.00	70.60	24.60	77.19	48.18
$2.00	30.60	-5.40	50.52	28.18
$1.00	-9.40	-35.40	23.85	8.18

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FARMING SYSTEMS RESEARCH IN ITS MACROPOLICY DIMENSIONS

George H. Axinn and Nancy W. Axinn[1]

INTRODUCTION

This paper considers some aspects of the recent evolution of farming systems approaches to agricultural research and extension, first by reviewing some of the perspectives of recent years, then by assessing the present state of the art and finally by looking ahead...at what appears to be a very bright future. This is an overview of three generations of problems and opportunities for the farming systems approach.

The first generation, from the authors' perspective, featured a concern for the whole farm as a system. It was an attempt to deal with particular components of the farm, realizing that they were components of a larger system. The first generation exposed both the linkages among the various components on the farm and the high levels of specialization within the agricultural research community that made it so difficult to respond to the farm as a system.

The second generation is a stage many are in, attempting to apply systems science to various types of farming systems, trying to understand the components and also the relationships among those components in agroclimatic ecosystems.

And looking ahead to a third generation of farming systems approaches, one can anticipate more attention to individual farming systems as a part of larger systems — and therefore part of communities, of regions, of nation-states and of an international diplomatic community of many nation-states.

The concept of systems within systems within systems is useful in farming systems research and extension, the concept that the components of those systems are linked and that a change in any component will affect, and be resisted by, the other components.

VIEWING THE FARM AS A SYSTEM

The first generation focused on the need for technologies that fit the small, mixed farming systems of Africa, Asia, the Caribbean and Latin America, and the emphasis was on the word fit. The lack of that fit had made problems for agricultural research and extension and pointed up the differences between a commodity approach to agricultural research and a farming systems approach. That lack also demonstrated the value of a systems approach and revealed some of the difficulties of team work in this field.

[1]Professor, Department of Resource Development, Michigan State University, East Lansing, MI, U.S.A.; International Consultant, 2513 Bentley Court, East Lansing, MI, U.S.A.

By the early 1970s, the international development assistance world was well aware that the technology from the agricultural research organizations did not fit the needs of small, mixed, farm-family ecosystems. Many of the agricultural extension organizations that had been developed in ministries of agriculture were failing to deliver either increases in food production or improvements in rural life for the majority of people.

These agricultural extension systems generally did not include a vital role for organizations of local people. Instead, they took the form of "delivery systems," designed to deliver "superior" technology from the center out to rural people who would somehow benefit from it (Axinn, 1987).

That type of extension system is dependent upon an agricultural research organization that generates, or borrows, the necessary and appropriate technology. Therefore, one of the great needs was for an agenda for agricultural research, one that was relevant to the small, mixed, labor-intensive, resource-poor farming systems on which most of the world's rural families live.

The international agricultural research centers were ahead of USAID and FAO in their enthusiasm for farming systems approaches. By the late 1970s, several of them were supporting farming systems programs. But it was difficult to overcome their own mandates to one crop, or to a commodity focus.

With a staff and an administrative structure geared to rice or to maize and wheat, there naturally evolved such phenomena as "cropping systems research and extension," "rice-based cropping systems research" and "maize in the cropping system" work.

Scientists tend to be different from members of the farm family. Farmers are forced by circumstance to consider the whole farm as a system. Scientists are so well disciplined in increasingly specialized fields that it is difficult to consider the farm as a complex system of such components as plants, livestock, people, soil, climate...and more. And even when scholars appreciate such concepts, basic organizational and financial mandates, as well as professional societies and journals, encourage a more narrow focus. Even though teams of dedicated specialists struggle to comprehend the whole farming system, they also tend to settle for much less.

In the first generation, this was related to a strong emphasis on "farming" and little or no attention to "systems." Few, if any, systems analysts were part of the FSR teams. Mostly, the teams were composed of agronomists, soil scientists and agricultural economists although, as Cernea and Guggenheim (1986) pointed out, anthropologists and rural sociologists had a crucial role to play. However, the application of systems science to the whole system was not a high priority in the last decade.

In Nepal, for example, where the authors were working, the government had a project, with international support, that tried to deal with

farming systems but only got as far as cropping systems. The result, in part, was the recommendation of maize varieties with higher grain yields than local varieties. And farmers were willing to plant them.

But the research teams failed to consider the high populations of ruminant animals on these farms and the dependence on corn stover as a livestock feed. Since the new maize varieties did not produce stover that was as high-quality as that from local varieties, farm families preferred to plant the local varieties. Their need to feed livestock had been overlooked in the selection criteria, and the new varieties simply did not fit the farming system. It was later obvious that the plant component was linked to the animal component, and that any change in either was dependent upon its impacts on the other.

The first generation of FSR work moved some of the research away from the research station to the farmer's field. And it achieved more concern for what would actually work on the farm. But the primary focus was on adapting the technologies developed at the international centers to the farms of "target" countries. There was little opportunity to take a problem-solving approach to whole farms as systems. Nevertheless, the idea took root.

The struggle in northeastern India is but one example of what is increasingly being attempted throughout the world. The second author has worked there with many Indian agricultural researchers in the Rice Based, Rain Fed, Resource Poor, Farming Systems Network. Like other farming systems networks, its early work employed rice breeders to find better varieties. Those few, like Dr. Maurya, who worked with farmers, listened to them, took guidance from them and even took germplasm from them developed genetic material that fit the system better than did earlier varieties.

But it is becoming increasingly evident to the research network, as they have applied the tools of farm management as part of a larger analysis and as they have suffered the capriciousness of the monsoon, that more attention must be given to crops other than rice. It is necessary to identify plants that can be grown under much drier conditions than average, and with more photoperiod flexibility. Also important is encouraging creative approaches to livestock components and even, perhaps, nonagricultural income-generating activities.

APPLYING SYSTEMS SCIENCE TO FARMING SYSTEMS

And so we come to the present state of farming systems work. As witnessed by this conference itself, and the increased emphasis on the "systems" aspects of a farming systems approach, the specialists have been joined by generalists, or perhaps some have learned to comprehend the more general context in which their specialization can contribute.

This diagram of a typical farm-family ecosystem (the upper diagram in Fig. 1), which the authors evolved a decade ago during work with farm-family ecosystems in Nepal, is similar to the conceptualizations that others have developed. It has helped us see the linkages; it has helped

us assess the flows of materials and energy among the various components; and it has forced us to consider components or subcomponents that may not have been on our agendas as we attempted careful description of farm-family ecosystems in their near environments (Axinn and Axinn, 1984).

As Fig. 1 illustrates, in the small, mixed, farm-family ecosystems in Nepal, three major components were identified: plants, animals and humans. Most of the production and the consumption of the system took place in those components. The smaller circle, "other," represents other household production, like the manufacture of tools for use in the home or field. The near environment of the farming system is represented by the other figures, which identify major sources or exchangers of materials and energy. The lines connecting these components with each other, and with outside systems, represent the links among the components.

In fieldwork, the annual quantities of flow of materials and energy through these linkages were estimated. That analysis, in turn, led us to conceptualize the recycling ratio.

Others are using similar conceptual models to assess the fit of technologies in particular types of farming systems. We have all discovered, for example, that tractors are appropriate for agriculture when there is a relative shortage of labor and a relative abundance of land and capital. But when agriculturalists recommended tractors where there was an abundance of labor and a relative scarcity of land and capital, the programs failed.

Similarly, when extensionists were asked to promote the use of mineral fertilizer in places and at times where the price of such fertilizers was high and the marginal net returns were low or negative, the extension program failed. Attempts to introduce deep wells with submersible electric pumps and diesel generators also failed when they were far from a fuel supply.

It has not been easy to find appropriate technology to be included in agricultural development programs. This has been a problem in programs where the sponsors wished to focus on poor farmers, small-scale farmers and the less advantaged rural people. Since the technology is either imported from other countries or generated by agricultural research establishments with an agenda focused on commodities, in many cases the technology did not fit the farming system.

The assumption with the contemporary farming systems development approach is that technology that fits the needs of farmers, particularly small-scale farmers, is not available and should be generated locally. The purpose is to provide extension personnel with technology tailored to meet the needs of farm people.

With this approach, program plans evolve slowly and may be different for each agroclimatic farm ecosystem type, since the program must take a holistic approach to the plants, the animals and the people in each location. Thus control of the research agenda could ideally be shared

jointly by local farm men and women, agricultural extension officers, and agricultural researchers. In each location, the agenda would fit the needs and interests of its clientele, and the clientele would be more likely to participate, adopt recommended practices and provide continuity to the agricultural development system.

This approach requires a partnership between agricultural research personnel and agricultural extension personnel. While other approaches state that there will be good communication between such personnel and well-established links among their organizations, too often that has not been the case. Also, while most technology developed by agricultural research personnel is intended to be "scale neutral" and beneficial to all sizes of farm holdings, agricultural research organizations have tended to use a commodity approach to generate technology appropriate for larger, commercial, market-oriented farmers who specialize in one type of crop or livestock (Dahlberg, 1986; Axinn, 1986; Flora and Tomecek, 1986a, 1986b and 1986c; Garrett, 1986; Shaner et al., 1982).

But the farming system approach also requires that research personnel go to the farm, listen to farming men and women and, in collaboration with them and extension personnel, try to understand the farm as a system. Components such as animals, plants and people must be understood, as well as soils, climate, topography, access to markets, price policies and any other relevant factors.

The shift in terminology from "farming systems research" to "farming systems research and extension" and then to "farming systems development" in this paper has been deliberate, and, the authors feel, more appropriate for the future. Those who participated in the farming systems meetings last year at Kansas State heard Dr. Friedrich of FAO headquarters in Rome use that terminology.

A recent FAO publication describes the following key features of farming systems development (FSD).

- FSD is an approach for development.

- FSD is based on active farmer participation.

- FSD regards the farm family/household as an integral part of the farming system.

- FSD envisages substantial training in the farming systems approach in order to strengthen national institutions and increase their effectiveness.

- FSD aims at being a sustainable approach (Friedrich, 1986).

The FSD approach, if considered only as a fad that appealed to USAID for Africa and to some of the international development agencies and whose star must dim as suddenly as it rose, is certainly a limited phenomenon. But the approach is much more than that. It rides the knife edge of what is available in science; it has the potential of correcting some of the most serious consequences of overspecialization in the

international, scientific and agricultural research community; and it has the potential for incorporating the traditional wisdom of indigenous knowledge systems.

FSD is working well in many countries. The Puebla project in Mexico was able to overcome some operational problems when it adopted this approach (Flora and Tomecek, 1986a, 1986b and 1986c). The approach was used in the Fourth Livestock Development Project in Ethiopia in 1986 and in several programs associated with the International Rice Research Institute in the Philippines and in other Asian and African countries. It is also being tested by ministries of agriculture in many countries.

In August 1984 a regional roundtable was organized in Chile to discuss issues related to extension and research, and this approach was explored by representatives from Brazil, Chile, Colombia, Costa Rica, Ecuador and Peru. In Bangkok in 1985, representatives from many Asian countries reported on the promise and problems of the FSD approach, under FAO auspices. And the activities in both francophone and anglophone Africa have been vigorously supported (Fresco and Poats, 1986).

But the contemporary manifestation of the approach has been criticized for being too narrow, too site specific and not sufficiently sensitive to the macro policy dimensions. Like any other system, the farming system is merely a component in a larger system.

Each farming system, including its technological, biological and physical aspects in its unique ecological niche, is a component of a larger system. This portrayed by the lower portion of the diagram in Fig. 1. And in addition to other farming systems in that agroecological environment, it is affected by, and it affects, the cultural, social, economic, administrative, political and diplomatic macrodimensions of the larger systems of which it is a component.

The farming system is not a closed system. It is not self-contained. It is an open system, interacting within a milieu of other systems. That's why the bottom of the diagram in Fig. 1 lists several additional macrodimensions that impinge upon a farming system, or any rural social system. This is the portion that Dr. Bea Paolucci, Michigan State University, called "the bucket." The "bucket" contains variables that make a difference to every farming system and that will be increasingly taken into account during the third generation of farming systems development.

RECOGNIZING FARMING SYSTEMS ARE PARTS OF LARGER SYSTEMS

The array of macroforces that impinge on the farming system provide the context in which any change in any one of the components will either be accepted or rejected by the system.

The diagram in Fig. 2 of the force field in which a particular farming system may be found is, again, an oversimplification of reality. It is shown to illustrate the concept — not to completely define it.

Certainly as new technologies are introduced into a farming system, they can change that system. But no new technology is introduced in a technical void; there were other technologies before, and the old technologies in the system, or in the minds of people in the system, will be a force for continuity of the "old" in that system and a force against introduction of the new and the different. And no technology operates independently of the other biological and physical forces in that farm-family ecosystem and its near environment.

The shift to an improved buffalo in a South Asian farm-family ecosystem might enable the women of that system to increase the production of fluid milk. However, that will be successful only if there is enough fodder to feed the new buffalo through the year. The fodder may come from the straw of grains produced on the farm, it may come from cuttings along the sides of the road, it may come from common village pasture areas, or it may come from cutting the leaves of fodder trees. But it must come from somewhere. Without meeting the biological and physical requirements, no technological change is likely to persist over time.

But those are not the only forces; there are cultural dimensions. The buffalo may outproduce the cow, but some cultural groups need the cow for religious purposes, and that need is as real as your need to wear clothing. Unless the buffalo can earn enough to pay for keeping the cow as well, the technical shift to a milking buffalo may not be acceptable.

There will also be social considerations. If the woman of the farm-family ecosystem owns the buffalo, her relative power in the household will increase. If her husband owns the buffalo, and particularly if the receipts from the sale of surplus milk go to him, her workload will be increased, and his power may be greater.

Similar social phenomena will affect the relative social position of the family among other families of the village. These phenomena often account for a high proportion of the variance in the acceptance of the improved buffalo.

The economic forces are being studied in farming systems research. Will the benefits to the family exceed the costs to the family? Can some kitchen-garden land be converted to fodder production for the buffalo? It it is, will the cash income from the sale of milk be sufficient to purchase fruits and vegetables no longer produced? Could it be more income than that? If it is less, why make the change?

And, of course, there are always administrative forces. If a cooling tank is installed in this district, it will be possible to take milk there any day in the year and be paid for it in cash. Milk will be collected at the cooling tank and transported to a large dairy-processing plant in the city. But administration of a series of milk-collection points at various distances from the city may be impossible with a centralized administrative system. All dairy-plant personnel will wish to be posted in the central city. No one will take a job at a remote milk-collection point if all promotions are in the central dairy plant. Administrative decentralization may be a necessary condition to

the expansion of the dairy-collection system. And that may, in turn, be necessary for year-round effective demand for fluid milk.

But if the cooling tank is installed in another district on the other side of the river, then the market will be available only during the dry season, when one can walk across the river with a container of milk. However, if the political power of the representative of the other district is stronger, it may not be politically feasible to have the collection point in this district. Political participation, perhaps by an organization of women who own milking buffalo, may be necessary; it could be a condition for that improved buffalo to be an acceptable change in the farming system.

The political forces are not the end of the line. In the diplomatic arena, it could be that far away in Europe and North America there is a surplus of dairy products. Your country had requested some food grains from the World Food Programme. Now they have negotiated an arrangement to accept 70,000 tons of dry milk powder in addition to the cereal grain. When this is reconstituted at the city dairy plant, there will be no need to collect from any of the new cooling stations for over 6 months.

And when your area's politician confronts the minister to ask how they could have done such a thing, the minister explains that he tried not to take the milk powder. He even traveled to Rome or to Washington to beg that only food grain be shipped, showing evidence that neither milk powder nor cooking oil were needed at all. In fact, imports of either would depress local prices, discourage local production and worsen the food security situation for the entire country.

But diplomatic power is like political and economic power. It belongs to the strong, not the weak. And the powerful donor nations may have forced the "gifts" of dry milk powder, because local politicians within those countries have their own problems with surplus dairy production.

Thus a simple technological innovation can be defeated by forces at any level: biological, physical, economic, cultural, social, administrative, political and even diplomatic. And, conversely, its acceptance might be enhanced at any level.

That is why it is the opinion of the authors that those concerned with farming systems development will increasingly take into account the whole range of macroforces that impinge on rural life. To do less will be self-defeating.

But that does not mean that every farming systems research project must do every level of analysis. It suggests that those who study farms as systems have an obligation to take into account all of the components of the farm-family ecosystem. And fortunately for us, there are other scholars, and they have other specializations.

In terms of how to do it, I suggest that it is important for each scholar doing farming systems research to be aware of the various levels of relevance. The best work probably will come from research addressed to one particular level. But that work itself is likely to be more

fruitful — likely to produce results that fit the farming system better — if it is done with awareness of the other levels.

Developing a rice variety that outproduces all others in a farming system is not likely to be valuable to the people of that farming system if the demand in nearby markets is for a rice with a much different set of cooking and eating characteristics. If it is more profitable for the farmers to grow the old variety, even with much less total production, they are likely to stay with the old variety.

When mineral fertilizer is overpriced in local markets, analysis of the larger economic, political and perhaps international diplomatic dimensions may be more relevant than farming systems research. In Karachi, they had to build new port facilities and expand internal transportation and storage in order to bring down the price of fertilizer in Pakistan. Other countries have had to stimulate internal production and allow imports to arrive duty free.

The authors are not suggesting that those who have developed some ability and skill in dealing with the whole farm as a system should abandon that and try to become political analysts. Instead, they are suggesting that a comprehensive, multilevel approach to farming systems may identify the other levels at which further research or changed policies are needed.

The point is that the macrodimensions make a difference. From one perspective, these forces set the limits of what can be done within the farming system. From another perspective, they suggest an agenda for collaborative research involving geographers, human ecologists, political scientists and others.

And not only are these macroforces relevant to technological innovation in the farming system — they are relevant to the nature of the organization and the reward system of agricultural research itself. Thus the politics of agricultural research and the administrative decentralization of agricultural research will become legitimate areas of study.

The third generation of farming systems approaches may include the whole range of activities from increased farm family participation in setting the research agenda to analysis of world diplomatic forces surrounding a particular potential technology. There might be more livestock on the small-scale farming systems in this part of Arkansas if the United States raised the import duties on beef, pork and mutton. There might be positive consequences for the rural poor in Central America. There might be higher prices in the fast food restaurants of Michigan. And there might not. These are researchable topics.

CONCLUSION

Thus one can affirm the importance of the macropolicy dimensions in identifying appropriate technology. Farming systems research must be able to take them into account. But excellent farming systems research

must be more than that. If it analyzes only the macro issues, it will fail. If it analyzes only the micro issues, it will fail. The value of a systems approach is in the assumption of open systems. The value is in the assumption of links among all the components and of the various levels of analysis.

With the farm-family ecosystem as the core and with cooperation among specialists and generalists in partnership with farm families, farming systems research can focus both up and down. It can focus down to such components as plants, animals and humans and further down to such subcomponents as rice and buffalo, soil and maize, goats and weather and to the needs and interests of people, people and people. And it must also focus up to the larger social systems of which each farm-family ecosystem is only a small component and up to milk-marketing networks and the international diplomacy of distributing surplus food.

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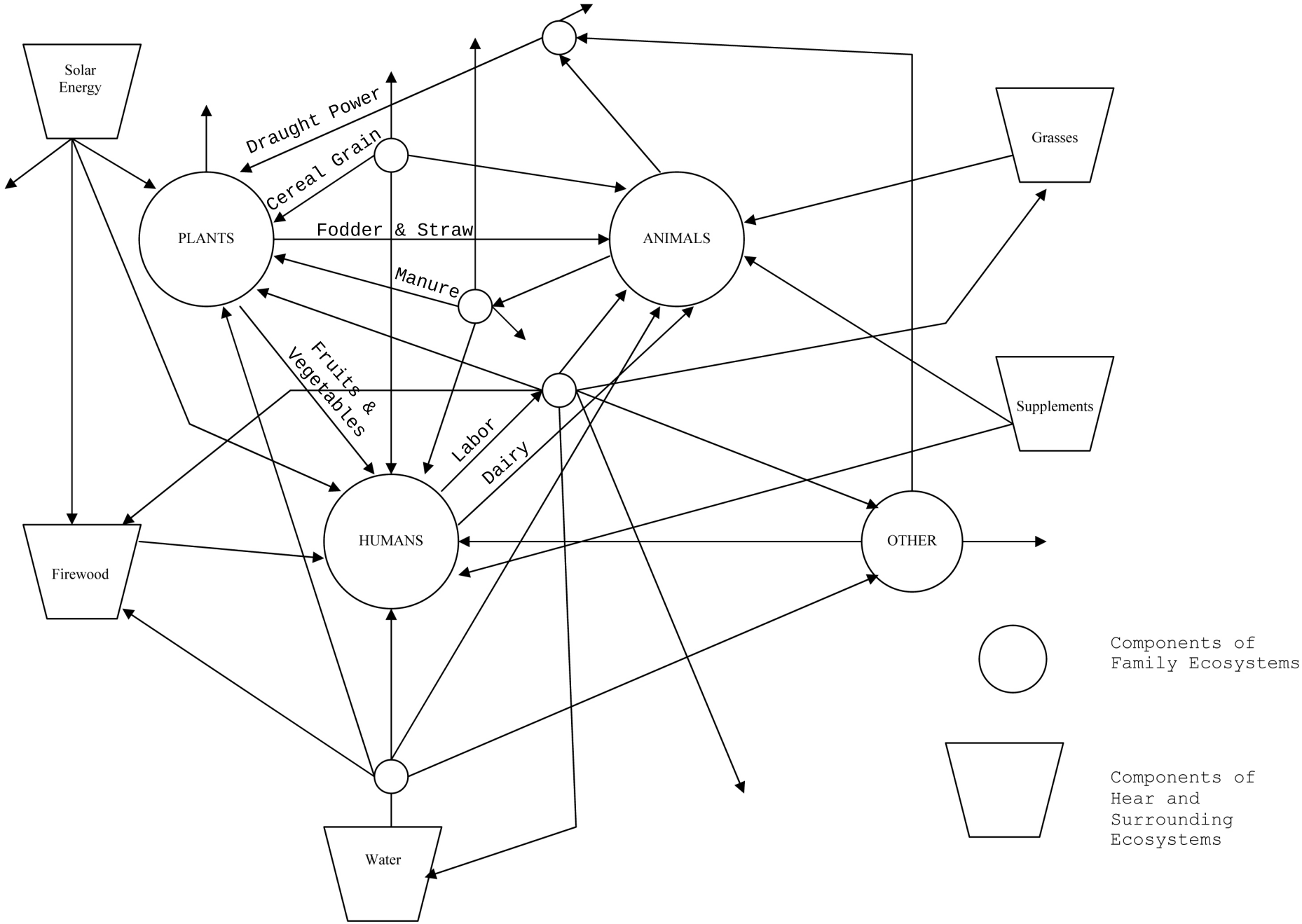

Fig. 1. Materials flow and energy transformation in a typical, small, mixed-farming system.

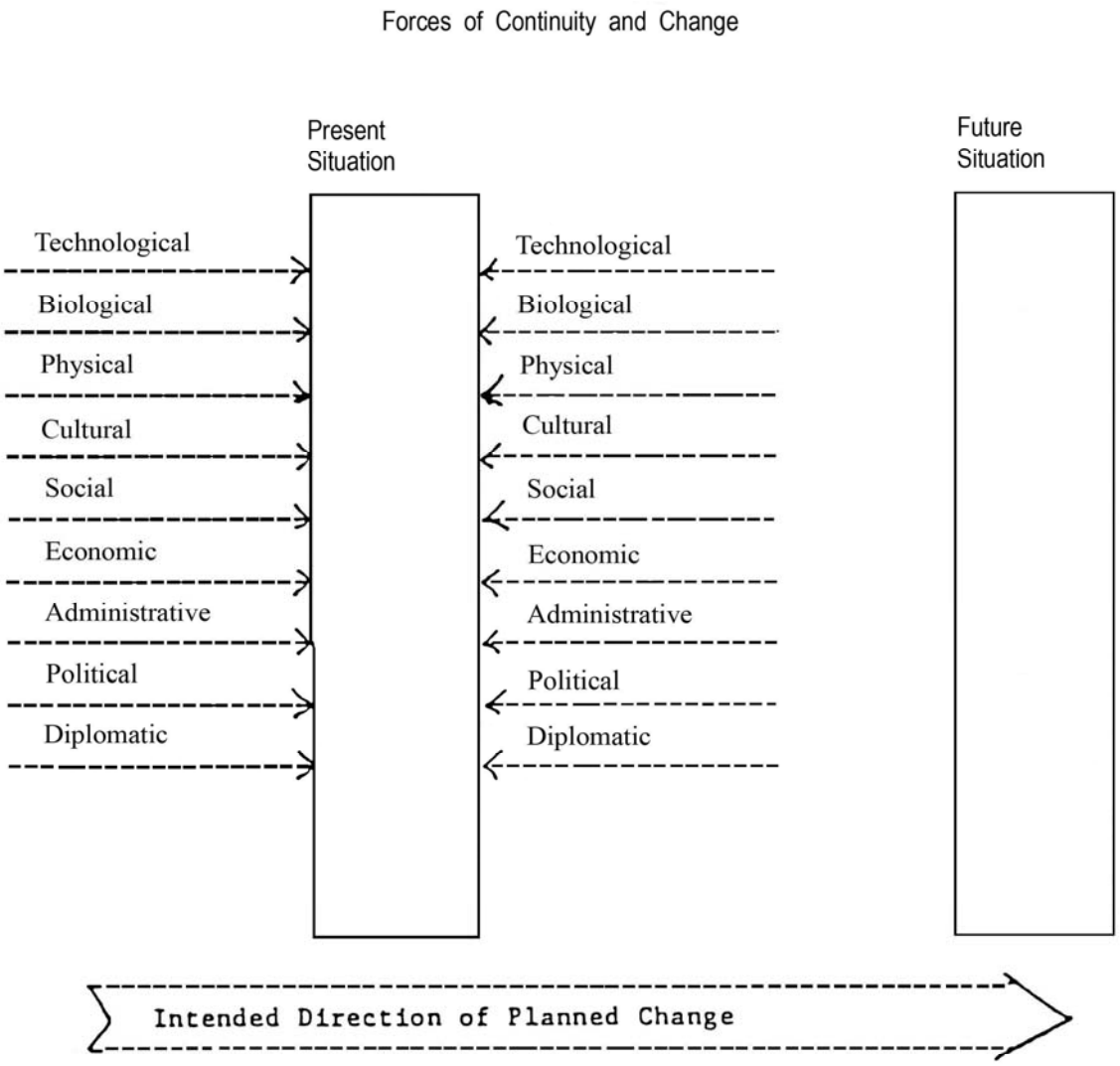

Fig. 2. Forces affecting adoption of technology.

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ORGANIZATION AND FUNCTIONING OF CHILEAN PEASANT FARMING SYSTEMS

Julio A. Berdegué, Miguel Diaz, Rodrigo Gracia
Sergio Gonzalez, Ivan Nazif and Ximena Quezada[1]

> The systemic [systems] question is essentially the question of the limitations of analytical procedures in science...The methodological problem of systems theory, then, is to come to terms with questions that, compared with the analytical-additive ones of classical science, are of a more general nature...(L. von Bertalanffy)

INTRODUCTION

El Salto and Los Aromos (latitude 37°12' S, longitude 72°23' W) are neighboring peasant villages (comunidades) located in the central valley of the province of BioBio, 500 km south of Santiago. The peasant farming systems at these sites were developed in 1976 as a result of Chile's Agrarian Reform (1964-1973) and Counterreform (1974-1977, approximately) processes.

The parcelero (or asignatario) peasants are characterized by their ownership of medium-sized farms, usually located in areas with good to excellent soils and climates, often in regions with irrigation and good communications. The farms have potential for increased production that could lead to higher incomes and better living conditions.

However, of the approximately 100,000 families that originally benefited from the Agrarian Reform, by 1986 only about 25,000 still owned their land. Of these, a small fraction joined the expansion of Chilean for-export agriculture, while the vast majority saw their productive and living standards stagnate or even decline.

This last group includes the peasant farming systems of El Salto and Los Aromos. Given the quality and quantity of their resources, the parceleros (medium-scale land owners) could become an anchor for future policies that aim at enhanced levels of food availability for the Chilean population.

More detailed discussions of the farming systems of El Salto and Los Aromos — as well as other locations — can be found in several of GIA's (Grupo de Investigaciones Agrarias) recent publications (GIA-AEDC, 1987; Berdegué and Larrain, 1987; Canales, 1987; Diaz, 1987; Gonzalez, 1987; Nazif and Pizarro, 1987).

[1]Grupo de Investigaciones Agrarias, Ricardo Matte Perez 0342, Providencia, Santiago, Chile.

PEASANT'S PROJECT AND SYSTEM'S PROGRAM

The keynote question of the 1987 FSR symposium, "How do systems work?" is addressed in this paper by examining the premise that the goal of the farming systems of El Salto and Los Aromos is to generate a global product (GP), i.e., a set of goods and services derived from the on-farm and off-farm activities of all members of the family unit.

At a minimum, the GP must replace all the inputs that are used in the productive cycles. That is, it must replace the labor force, restore the natural resources and preserve the value of the farm's assets. If past experience indicates to the peasant family that this minimum is assured, then it will attempt to generate a net growth of the quantity and(or) quality of one or more of the factors of production.

It is pertinent to distinguish between the peasant family's objectives (its project) and the events in the system (the system's program). At any given moment, the congruity of the relationship between the peasant's project and the system's program will be greater if the system's state is such that the values of its attributes — as a whole systemic unit — are optimal:

- if the system is balanced, meaning that its component elements are present in adequate relative proportions

- if the system is synchronized, meaning that there is an adequate relative timing between its events

- if the system's style is conducive to the peasant's objectives, meaning that its component elements make the attainment of the family's project feasible

It is also necessary to emphasize that the peasants' culture will strongly influence the decision-making process. For the purpose of this paper it is sufficient to establish that the technological and productive decisions are based as much on cost/benefit analysis as on symbolic or ideological values. Hence, the relationship between the peasant's project and the system's program is particularly complex and at times even contradictory or paradoxical, as is shown by Canales (1987). In the case of the parcelero peasants, a decision to implement a given activity, is the result of the interplay between economic calculations of the possibilities and presumable results of such activity and cultural symbols or aspirations.

To develop the productive processes that will lead to a GP, the peasants make decisions concerning the organization, distribution and use of the system's component elements. Of particular importance, given their impact upon the system as a whole, are those decisions that concern system inputs that are present in limited quantities and that are indispensable for the functioning of more than one subsystem.

Those elements will link two or more subsystems in a single chain of events, since the value of the limiting input in one subsystem will determine its value in another. Hence, decisions concerning these

resources will lead, to a great extent, to a vast array of interactions among the subsystems, the result of which will be a GP.

To understand how the system produces a given GP, it is helpful to describe the management of some of the main productive factors in El Salto and Los Aromos.

MANAGEMENT OF PRODUCTIVE FACTORS

Generally speaking, different resources play different roles in El Salto and Los Aromos.

Land

Land is the main local resource. The above-average (for peasant agriculture) size of the parcelero holdings and the quality of the soils, distinguish these farming systems from the vast majority of the Chilean peasant farming systems. The value of the land represents 70% of the total worth of these families (as compared with about 10% for other groups of peasants). Land, then, is the main source of opportunities for the peasants of El Salto and Los Aromos.

The average farm size is 29.25 ha (Table 1). Land is evenly distributed in these comunidades (villages), as shown by a Gini coefficient of only 0.18.

On average, each family allocates 51% of the land to crops and artificial pastures; 44% to natural pastures; and *5%* to the house and its environs. The main crops — wheat (Triticum aestivum), beans (Phaseolus vulgaris) and red clover (Trifolium pratense) — occupy, respectively, 17%, 18% and 20% of the total farm area. A small fraction of wheat and clover is grown as mixed crops during the last 6 months of the 10-month cycle of the cereal stand. Up to 13 other crops are grown on small plots.

The area planted to each of the three main crops has remained constant during the last three agricultural cycles, despite significant fluctuations in the market prices of the crops. Studies of the decision-making process in these farming systems lead us to believe that the area planted to crops is, to a large extent, dependent on available family labor.

The peasants of El Salto and Los Aromos know precisely the amount of labor that is necessary to maintain a unit of area for each of their crops. Depending on the amount of family labor that is available for on-farm activities, they will plant as large an area as possible.

Wheat, the main crop and basic component of the diet, has precedence in the assignment of land. These peasants consider it necessary to plant wheat in at least two different fields, to reduce the danger of losing their crop because of cattle and(or) flood damage. Since the farms are subdivided into fields of 2 ha to 4 ha each, the average area of wheat

ranges from 4 ha to 8 ha (this decision-making process is modeled in Fig. 1).

Winter wheat follows spring beans in the crop rotation. Hence, the area occupied by the legume and other minor spring crops will determine the wheat design described above (Fig. 2).

The area that is used mainly to sustain cattle and milk production covers 60% of the available land, including both natural and red clover pastures (Tables 2 and 3). Although 93% of the land is suitable for cropping, and 76% is irrigated, natural pastures and similar areas that support livestock add up to 37% of the total farm area.

In the optimal crop rotation, each field should be plowed 2 consecutive years in a cycle of 5. However, 40% of the land is plowed only once every 6 or more years while other areas of the farm are cropped yearly. Except for small and well-defined areas, the soils are of uniform quality.

The hypothesis that the prevailing crop rotation preserves the soil's quality must be rejected because 65% of the soils show signs of mild to severe deterioration. Additionally, the vegetation of 75% of the land has been classified as biologically overexploited, mainly as a consequence of overgrazing (Gonzalez, 1987).

Considering the soil quality and the size of the farms, on the average approximately 40% of the soils of each farm are underused.

Labor

Labor is the main limiting factor for these farming systems. Also, labor is a limiting factor in a qualitative sense because of the peasant families' relative lack of information and farm management abilities.

On average, each family has 1,649 person-days per month (PD/mo) of available labor (Table 4). Of this, only 48% (798 PD/mo) is available for on-farm activities, of which only 395 PD/year are invested in the main productive farm activities.

The decision to divert one-half of the family labor to off-farm activities is highly meaningful. It implies that families want goods, services or income that they do not or cannot obtain from their farms.

In some cases, the benefit of off-farm activities is a regular flow of cash that is less risky than farm income. In other cases, the parceleros give priority to a medium-term benefit: the training of their children, typically as agricultural or mechanical technicians. The peasant "sacrifices" on-farm production in exchange for benefits that cannot be obtained on the farm. Such benefits contribute to the achievement of the family's goals, as does crop production and income derived from milk sales.

To complement family labor, an additional 112 nonfamily PD/year are required, on the average, by each family. Thus, of a total of 517

PD/year invested in on-farm activities, 78% is contributed by the family. The composition of the total labor force will vary according to the different strategies implemented on each farm (Table 5).

This amount of family labor is insufficient in two ways:

1. **The concentration at a given time of several labor-consuming tasks in different crops and subsystems results in a labor shortage that is due to a lack of synchrony among the production activities.**

The seasonal labor requirements for wheat and beans (per 4.9 ha and 5.6 ha, respectively) are seen in the inserts in Fig. 1 and 2 while Fig. 3 shows their overlap. Wheat requires the most labor in March (for soil preparation) and in April (for soil preparation and seeding). Beans have two critical periods: in October and November (for soil preparation and planting) and in January and February (for weed control and harvesting). In November the harvest of the clover pasture demands an additional 14 PD/ha. These labor requirements cannot all be provided by the family, as is shown in Fig. 4.

As a result of this bottleneck, the peasants postpone or do not complete a number of necessary tasks in each of the crops competing for labor. The graph in Fig. 5 compares the labor use on one Los Aromos farm with the requirements that originate when the farm owner answers the question, "What is the optimum timing for the tasks that you consider necessary in each crop?" There is a difference between what the peasant would like to do and what he must do given the resources under his control.

The low yields obtained on these peasant farms are, to a large extent, due to a labor deficit resulting from unsynchronized system activities.

2. **Labor is also insufficient in the sense that it limits the farm area that can be planted and managed each year by the peasant family**.

Table 6 presents an estimation of the maximum amount of land that could be actively used each year if all family labor was devoted to farm activities. Under this condition, the maximum average area planted to crops could increase 50%, but it would still be less than the available area. We estimate that the amount of labor that would be needed to cultivate 100% of the available land would be 100% greater than what is currently invested in on-farm activities (Table 6).

This labor constraint is characterized as an imbalance in the relative proportions of land and labor. It limits the total crop and livestock production that a family can obtain each year.

Capital

Capital, in particular money, determines the relative use of land and labor. The available cash is sufficient to sustain the present technological practices. Money capital is fixed in the short term, given the extreme reluctance of these peasants to participate in the

financial and credit markets. Thus, in relation to land, capital is a limiting factor.

The attitude towards credit is affected by past experience. A significant proportion of the original parceleros of El Salto and Los Aromos lost all or part of their land when they were unable to repay the debts that they incurred to buy their farms in 1976. Approximately 25% of the land originally owned by the peasants of El Salto and Los Aromos has been sold to repay the parceleros debts.

The management of money capital varies among different groups of peasant families, loosely defined as socioeconomic strata (GIA-AEDC, 1987). The figures in Table 7 show that there is a direct relationship between the strata and the value of the family's patrimony. If the average patrimony of the high-stratum families is made equal to 100, the relative figures are 60 for the medium stratum and 40 for the low stratum. The patrimonies of all these families were roughly equal at the time they received their land in 1976. Additionally, on average the low-stratum peasants have outstanding debts that are equal to 46% of their assets; these debts originated in 1976 or soon after when these families bought their land, animals and equipment.

The peasant's relationship with financial markets is summarized by observing the degree of monetarization of the farm's economy. The data in Table 8 show that the lower the stratum, the less money is used in the economic activities. While 42% of the production of the low stratum corresponds to nonmonetary transactions, the figure is only 35% for the medium stratum and 10% for the high stratum.

Averaging all products, the high-stratum peasants sell 83% of their production in the market, while both the medium-stratum and low-stratum peasants sell about 60%.

Figure 6 shows the monthly flow of cash expenses and income for crop and livestock production. The data suggest that the peasants' decisions on what, how and when to produce are affected by the family's financial resources.

Economic events are concentrated around specific productive activities. The management of money is governed by design decisions, that is to say, by the peasant's production plan at the start of the agricultural cycle. There is no evidence of short-term economic events resulting from a reaction to unexpected external stimuli. Hence, the rhythm of economic events is governed by the rhythm of production, given the absence of financial management of a money surplus at the end of the agricultural cycle.

Two general conclusions seem applicable to all the farms, regardless of the socioeconomic stratification. First, in the short term (e.g., one agricultural year) the amount of capital and labor are fixed. If the planted area is increased, the result will be lower capital-per-hectare and labor-per-hectare ratios, and thus lower yields. It is in this sense that capital plays a regulatory role in the system.

Second, these peasants set their economic objectives in terms of expected production. These parceleros do not seek maximum profits in all crops or subsystems; while the basic role of some of the components of the system is to yield as high a profit as possible, this profit must contribute to a GP. The economic activities of the farm are organized so as to optimize this GP, not to maximize short-term profits.

RELATIONSHIP BETWEEN STRUCTURE AND FUNCTION: HOW SYSTEMS WORK

These peasants have evolved a technological and crop structure that allows them to use the irrigated fraction of their land for crop production.

The remainder of the land has been assigned to a subsystem (livestock, production) with the main purpose of providing stability to the system. This subsystem ensures stability by providing a daily cash income sufficient to cover the consumption expenses of the family, as well as most of the operating costs of agricultural production, and by being a depository of surplus capital (easily transformed into cash in case of emergency) that cannot be absorbed by the crop subsystem. The crop subsystem governs the organization and use of most of the system resources and allows the parceleros to improve their living standards.

Labor requirements are partially adjusted to this organization of the system. A permanent nucleus of family labor (husband, wife and perhaps one or more of their children) conducts the farm's activities during most of the year. At critical times nonfamily labor is hired. The number of workers that can be productively mobilized is determined partly by the number and types of tools, machines, horses and other such capital goods that the family has at its disposal. Additionally, the number of hired workers is limited by the parcelero's ability to organize and administer the use of their time; hired labor is directed and supervised by a family member working side-by-side with the nonfamily workers.

Since, as has been mentioned, this overlapping of activities results in labor shortages during parts of the productive cycle, it is pertinent to ask why these systems do not contain a higher proportion of capital relative to land and labor.

In the case of at least 30% of the farms (those in the low stratum), it is apparent that capital is a scarce resource. In the case of the medium-stratum and high-stratum families, higher capital/land or capital/labor ratios would imply new balances between the crop and livestock subsystems, as well as new roles for each of them vis-à-vis the composition of the GP, depending on how the freed labor is distributed among the different crops, activities and subsystems. Significant changes in the technological structure would lead to changes in the system's functional and structural nature.

At the village level the technology used to grow crops is similar on all farms. Because the type and quantity of agricultural inputs are

similar, production from the crop subsystem will depend, to a large extent, on the amount of labor used per unit of area.

For the bean crop, yields and labor are related by the equation $Y = 3.02 + 0.292 X$ ($r = 0.93$). For the wheat crop, the relationship is $Y = 0.626 + 0.937 X$ ($r = 0.943$),on condition that the relationship is calculated for wheat growing in soils of uniform quality (the parceleros whose farms border the Laja River tend to plant as much of their wheat as possible on the more fertile fields adjacent to the river margins).

This organization of the farming system implies the underuse of a large fraction of the farm's soils. The livestock subsystem depends on the use of a large proportion of the available land, primarily as natural pastures. While the value of the animal and soil components is 66% of the farm's assets, the livestock subsystem receives only 24% of the operational capital and 34% of the labor but 67% of the land. In exchange, the livestock subsystem generates 36% of the cash income.

The net returns per unit of labor and land for the main subsystems are shown in Table 9. Considering only the monetary returns, the crop subsystem's dollar-per-hectare ratio is 163% greater than that of the livestock subsystem. However, the livestock subsystem shows a dollar-per-person-day ratio that is 35% greater than that of the crop subsystem. On the other hand, if a money value is assigned to the family labor and the family-consumed goods, then the crop subsystem also shows a higher dollar-to-person-day ratio than that of the livestock subsystem.

In conclusion, with respect to the use of labor, animal production is an economically attractive activity, but it results in an underuse of the land. The livestock subsystem as it is now structured represents a convenient adjustment to the limitations imposed by the labor deficits, but it affects the system's ability to exploit the available land as its main source of opportunity for growth.

HYPOTHESIS ABOUT THE EVOLUTION OF THE FARMING SYSTEMS

The study of the evolution of these farming systems requires data compiled over a number of years. Since this study is still under way, no final conclusions can be proposed. What follows, then, should be considered as a general hypothesis that is based on partial data and, primarily, on what we know about the peasants' explicit goals and attitudes concerning their systems' programs.

At the system level, the high-stratum peasants of El Salto and Los Aromos are attempting to obtain a GP that allows net growth of several of the system's components. At the same time, they are altering risk management in the sense that the stability of the system is based on a more efficient use of the resources under their control rather than on a GP composed of elements subject to widely different kinds of stimuli.

The systems program is characterized by a more economical use of the available land. While efforts to increase the wheat and bean yields are

important, the main emphasis is placed on finding ways to inject a greater dynamism into the livestock, subsystem.

As can be seen in the flow diagram of the subsystem (Fig. 7), milk, production is highly seasonal, and average annual yields are low (1,052 liters/cow/year). The flow diagram of the subsystem shows that the clover pastures are not harvested; rather, their only use is for grazing. As winter sets in, both the natural and artificial pastures become dormant, and livestock suffer from a severe shortage of feed. As a consequence, average monthly yields per cow drop from a high of 160 liters/cow/month in December and January to 35 liters/cow/month in mid-winter.

To reduce this extreme fluctuation, the high-stratum peasants cut and store the clover forage to have a reserve for the winter months. Since this alternative is highly labor-intensive, labor must be freed from the crop subsystem. For this purpose, a number of animal-drawn machines have been gradually introduced, tested, modified and incorporated into the technological structure. Within the past few years these farmers have shifted from manual practices to hired mechanized services for harvesting wheat and thrashing beans. These services have been incorporated by most of the farms, except for some in the low stratum. Since the option of asking for investment loans is still firmly rejected by all the peasants of El Salto and Los Aromos, mechanization has been partial and erratic.

The objective of the medium-stratum peasant families is to reproduce the organization of the farming systems as described above. The systems program of the medium-stratum peasants gives priority to the stability of the GP over increases in yields or production levels. Significant changes in the overall structure of the system are not pursued.

However, this should not be interpreted as meaning a static condition or, as is commonly expressed in the literature, as a resistance to change. In effect, all the peasants of El Salto and Los Aromos are involved in a process of learning and improving their livelihood from the land they acquired in 1976. It should be added that this process is not isolated from the evolution of Chilean society and agriculture. The result is a process of continual change and re-creation of their culture (and, hence, of their goals and decision-making criteria) for which Canales (1987) has coined the term <u>campesinidad</u> <u>aprendida</u>.

Off-farm activities are a basic element of the strategy of these medium-stratum families for ensuring the system's stability. Close to two-thirds of family labor is invested in permanent off-farm activities in return for wages that amount to 47% of their net cash flow. However, the average net return per person engaged in off-farm activities is only 44% of that of the on-farm labor. In addition, diverting family labor to off-farm activities imposes several significant bottlenecks on the farming system. Thus, the economic data confirm the results of the studies on the decision-making process. These farmers are willing to trade increased production for greater stability that is derived from less risky sources of income.

It is in the case of the medium-stratum farming systems where, perhaps, there is greater similarity between the peasant's project and the system's program. Thus, it should not be surprising that the net cash surplus at year end (including all sources of income) is 20% greater than that of the high-stratum families (but their assets are only 67% of those of the high-stratum families).

The low-stratum families' project is, like that of their medium-stratum neighbors, one that strives towards stability rather than growth. However, the farming systems of these parceleros leads to a progressive deterioration, measurable by their deteriorating living conditions and income levels, by the loss of their property, by the decreased quality of their soils and by the fall in the value of the patrimony.

The peasant's project of stabilizing the family's and system's condition translates into a tendency towards subsistence agriculture, since the marketable product surplus is much reduced or is nonexistent, given that the peasants' average yields are often less than 50% of those of the medium and high strata. For example, the wheat crop has an average deficit of $15,024/ha if a monetary value is assigned to family labor and family-consumed farm products, as is shown in Table 10; production is in many instances not sufficient to supply the family's annual needs.

Given such a state, the livestock subsystem must play to the full its stabilizing role, while still operating under the same conditions that were described above. The money and goods derived from the livestock subsystem represent 30% of the total gross value of the system's products, as compared to 20% for the medium-stratum families (Table 10).

In addition, the low-stratum families engage (to a larger degree than their neighbors) in several different types of land-, cattle- and labor-sharing arrangements with other peasants (see, for example, Tables 1 and 5). While these practices bring the benefit of a redistribution of scarce resources, they also represent a mechanism by which the low-stratum peasants yield partial control of their own resources to other peasants.

The sale of cattle and sections of land are mechanisms used by these peasants to raise enough money to sever their ties with the credit markets, which are seen as the main obstacle to the survival of the farming system and the family farm.

This tendency towards a redefinition of the system style is always partial, since these peasants are reticent to let go of their property. Additionally, since the amount of available land is more than needed for subsistence, peasants require additional resources to produce a marketable surplus to cover the financial costs of the land.

Unless these low-stratum peasants benefit from special support policies, their fate will be the same as that of the 28% of the original parcelero families of El Salto and Los Aromos who have had to give up their land.

CONCLUSIONS

The peasant farms of El Salto and Los Aromos have reached a state in which their different subsystems interact to produce a global product that allows the achievement of the goals of some of the peasant families (medium stratum) but hinders those of almost one-half of the population.

In addition, the peasant farms have difficulty in establishing balance, synchrony and style of their component elements, which could lead to a more optimum state and to a greater coherence between the peasants' projects and the systems' programs. Because of these difficulties, these farming systems are more vulnerable to the stimuli that they receive from their regional and national surroundings.

A more optimal state of these farming systems would require changes that address the constraints of insufficient labor and capital and that permit the peasant families to take fuller advantage of the available land resources. Such changes can take place only if new labor-capital-land combinations are established.

Given the fact that these farming systems have only a 12-year history, it is presumable that they are still undergoing significant transformation, which requires further study.

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Table 1. Use of the soil.

	High stratum		Medium stratum		Low stratum		Weighted average	
Wheat	2.00	5.12	3.96	15.60	4.25[a]	13.14	3.76	12.85
Wheat/clover	4.45	11.35	--	--	1.76	5.44	1.14	3.70
Bean	5.15	13.17	3.50	13.78	8.58[b]	26.52	5.19	17.74
Minor crops	0.13	0.33	0.35	1.38	--	--	0.12	0.42
Red stover	4.30	10.97	4.50	17.73	5.37	16.60	4.72	16.14
Nat. pastures	15.76	40.21	6.73	26.50	8.75	27.05	8.60	29.40
House	1.29	3.29	1.50	5.91	1.23	3.80	1.39	4.75
Other	6.11	15.59	4.85	19.10	2.41	7.45	4.33	14.80
Total	39.19	100.00	25.39	100.00	32.35	100.00	29.25	100.00

[a]38% of the wheat is share-cropped.

[b]29% of the beans are share-cropped.

Table 2. Use of the soil, by socioeconomic stratum, for crop and livestock subsystems.

Stratum	Crop subsystem		Livestock subsystem	
	Ha	%	Ha	%
High	11.73	30.0	26.17	66.8
Medium	7.81	30.8	16.08	63.3
Low	14.59	45.1	16.53	51.1
Weighted average	10.21	35.0	17.65	60.3

Table 3. Use of the soil for the crop and livestock subsystems

	Ha	%
Crop subsystem		
Wheat	4.90	48.0
Beans	5.19	50.8
Other	0.12	1.2
Total	10.21	100.0
Livestock subsystem		
Red clover	4.72	26.7
Nat. pastures	8.60	48.7
Other	4.33	24.6
Total	17.65	100.0

Table 4. Availability of family labor (number of persons and person-days).

Stratum	Persons in family	EAP[1]	Total PD/year	Off-farm PD/year	On-farm PD/year
High	6.00	4.5	1,436.4	478.8	957.6
Medium	10.00	6.0	1,915.2	957.6	957.6
Low	6.00	5.0	1,596.0	1,117.1	478.9
Average	7.33	5.2	1,649.2	851.2	798.0

[1]Economically active population = family members 14 to 65 years old.

Table 5. Use of labor in the crop subsystem, by stratum and type of worker (person-days/year).

Stratum	Head of family	Other family	Neighbors	Hired	Share-crop	Total family		Total nonfamily		Total
						PD	%	PD	%	PD
High	181.4	248.3	28.7	80.5	--	429.7	79.8	109.2	20.2	538.9
Medium	247.5	142.0	19.1	182.8	--	389.5	65.9	201.9	34.1	591.4
Low	199.6	166.4	31.6	22.1	14.2	366.0	87.2	53.7	12.8	419.7
Average	209.5	185.6	24.5	95.1	4.7	395.1	77.6	121.6	22.4	516.7

Table 6. Estimations of maximum crop area (given labor availability) and of maximum labor use

Stratum	Cropped area (ha)	Farm size (ha)	Labor use (PD/yr)	Maximum area		Maximum labor	
				Total (ha)	Change (ha)	Total (PD)	Change (PD)
High	16.03	39.19	538.9	28.5	12.5	1316.8	777.9
Medium	12.31	25.39	591.4	20.0	20.0	1218.7	627.3
Low	19.96	32.35	419.7	22.8	22.8	679.4	259.7
Average	16.10	32.31	516.7	23.8	23.8	1071.6	555.0
Weighted average	14.93	29.25					

Table 7. Assets and liabilities of parcelero peasants, by socioeconoimic stratum (Chilean $).[1]

Stratum	Assets			Liabilities		Patrimony
	Liquid	Fixed	Total	Short term	Long term	
High	1,258,000	3,556,000	4,814,000	0	0	4,814,000
Medium	563,000	2,690,056	3,253,056	147,818	147,818	3,105,238
Low	741,700	3,010,537	3,752,237	1,554,892	174,691	2,022,654
Average	854,233	3,085,531	3,939,764	567,570	107,503	3,313,964

[1]One Chilean dollar equals US$0,004.

Table 8. Income and expenses, in money and goods (Chilean $).[1]

	Stratum		
	High	Medium	Low
1. Income	1,128,147	846,975	600,594
Money	938,327	536,045	364,804
Goods	189,820	310,930	235,790
Goods/money	16.80%	36.70%	39.30%
2. Expenses	280,225	227,043	354,286
Money	174,460	134,248	220,816
Goods	105,765	92,795	133,470
Goods/money	37.70%	40.90%	37.70%
3. Net Income	847,892	619,932	246,306
Money	763,867	401,797	143,989
Goods	84,025	218,135	102,317
Goods/money	9.95%	35.10%	41.50%

[1]One Chilean dollar equals US$0,004.

Table 9. Net returns per unit of land and labor (including monetary and nonmonetary transactions) (Chilean $)[1]

Crop/stratum	$/hectare	$/person-day
Wheat		
High	19.323	1.501
Medium	38.193	1.24
Low	(1.941)	(172)
Beans		
High	69.093	1.715
Medium	92.002	1.621
Low	17.858	1.51
Livestock		
High	9.58	1.56
Medium	8.154	765
Low	2.487	462
Other		
High	22.313	1.569
Medium	24.406	998
Low	5.898	591

[1]0ne Chilean dollar equals US$0,004.

Table 10. Income and expenses by activity by socioeconomic stratum (includes monetary and nonmonetary transactions)(Chilean $)1.

		Stratum		
		High	Medium	Low
I.	Income	1,128,147	846,975	600,594
	Wheat	218,400	244,800	123,660
	Beans	470,960	379,320	269,120
	Livestock	348,787	167,355	178,274
	Other	90,000	55,500	29,600
II.	Expenses	280,225	227,043	354,286
	Wheat	94,730	93,556	138,684
	Beans	90,950	37,311	82,189
	Livestock	81,315	36,231	121,573
	Other	13,260	39,945	11,890
III.	Net Returns	847,892	619,932	246,308
	Wheat	123,670	151,244	(15,024)
	Beans	380,010	322,009	186,981
	Livestock	267,472	131,124	56,701
	Other	76,740	15,555	17,710

[1] One Chilean dollar equals US $0.004

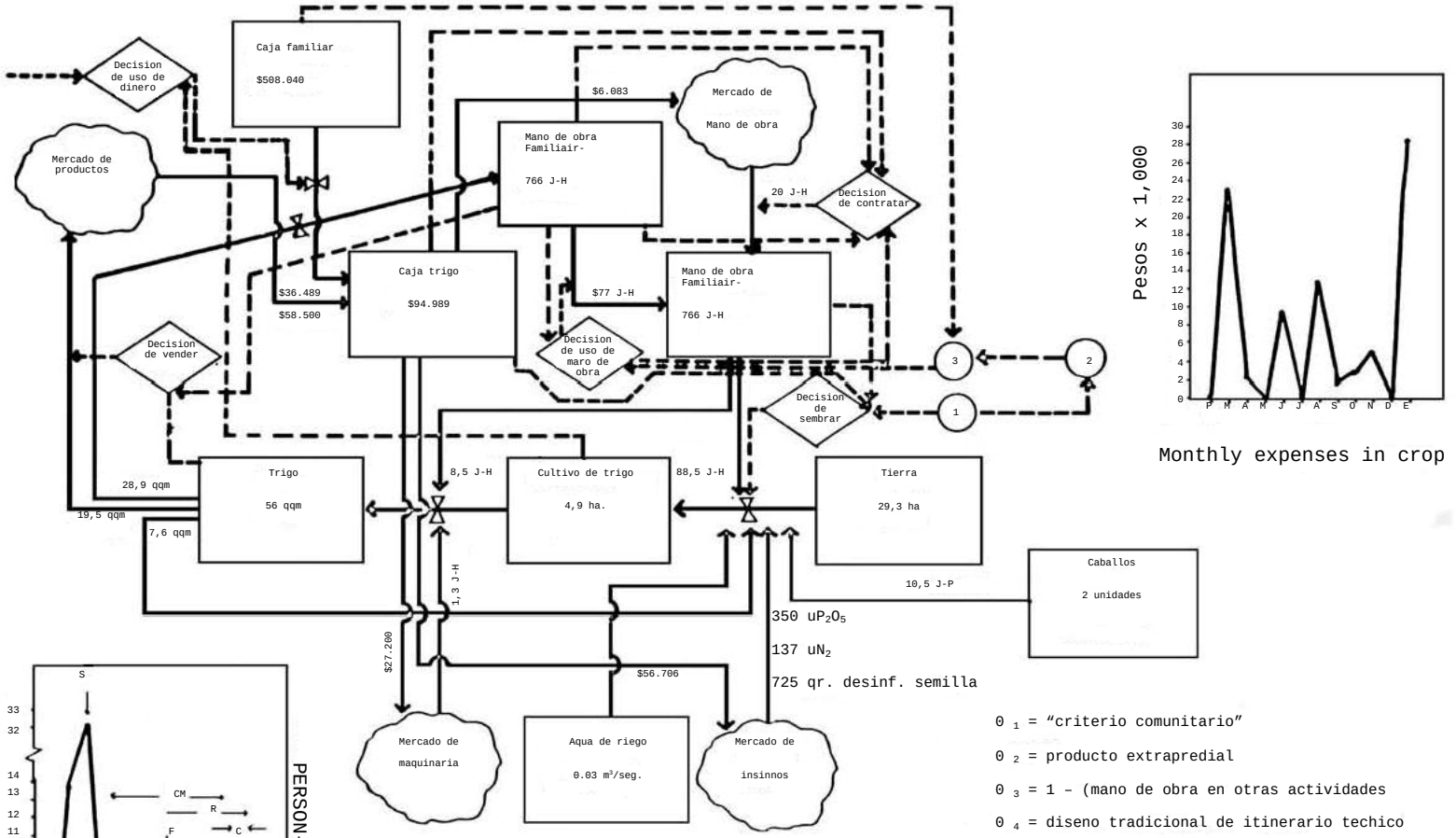


Fig. 1. Flow diagram of the wheat crop. Mean value of three strata.

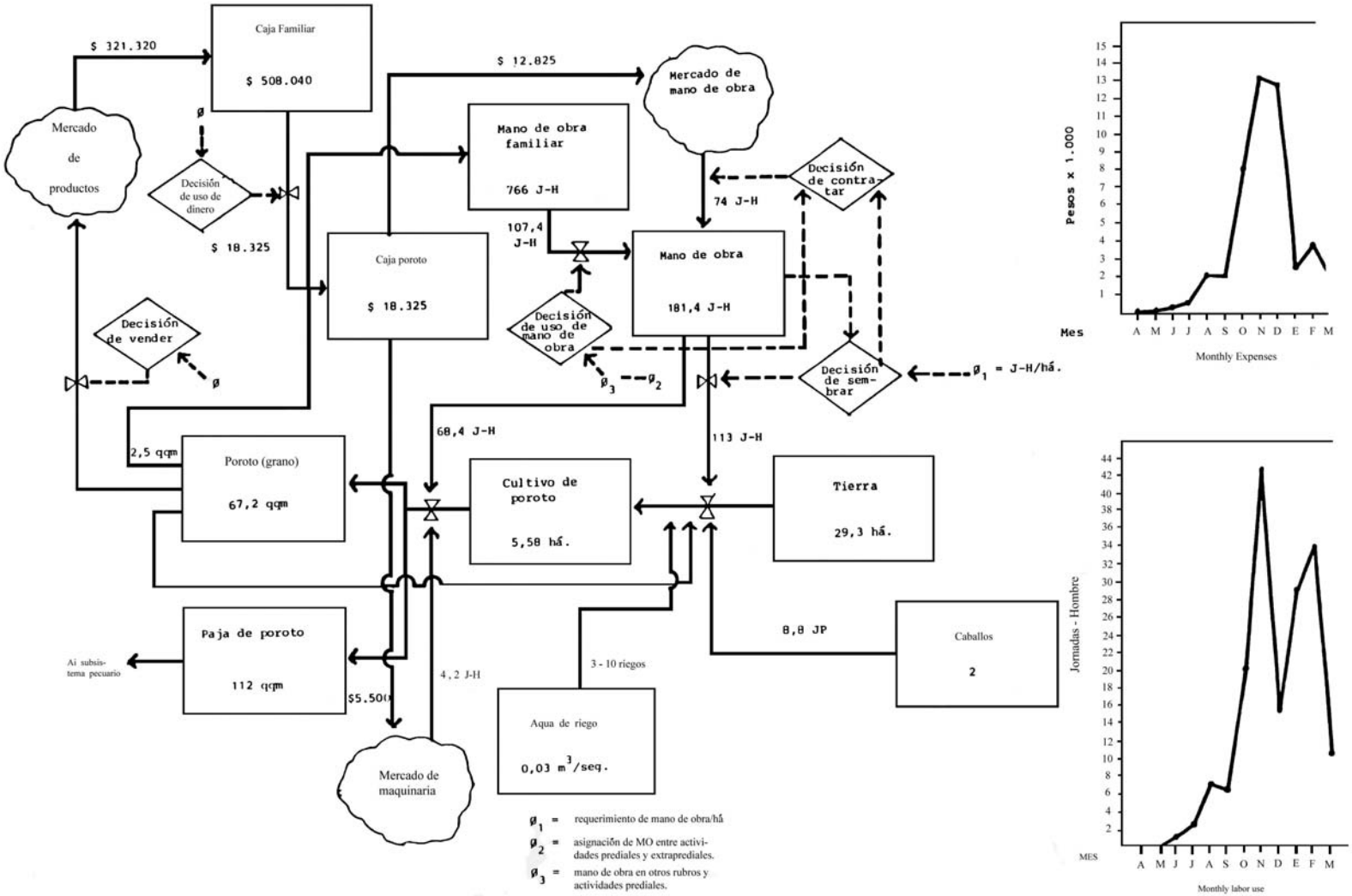


Fig. 2. Flow diagram of the bean crop. Mean values of three strata.

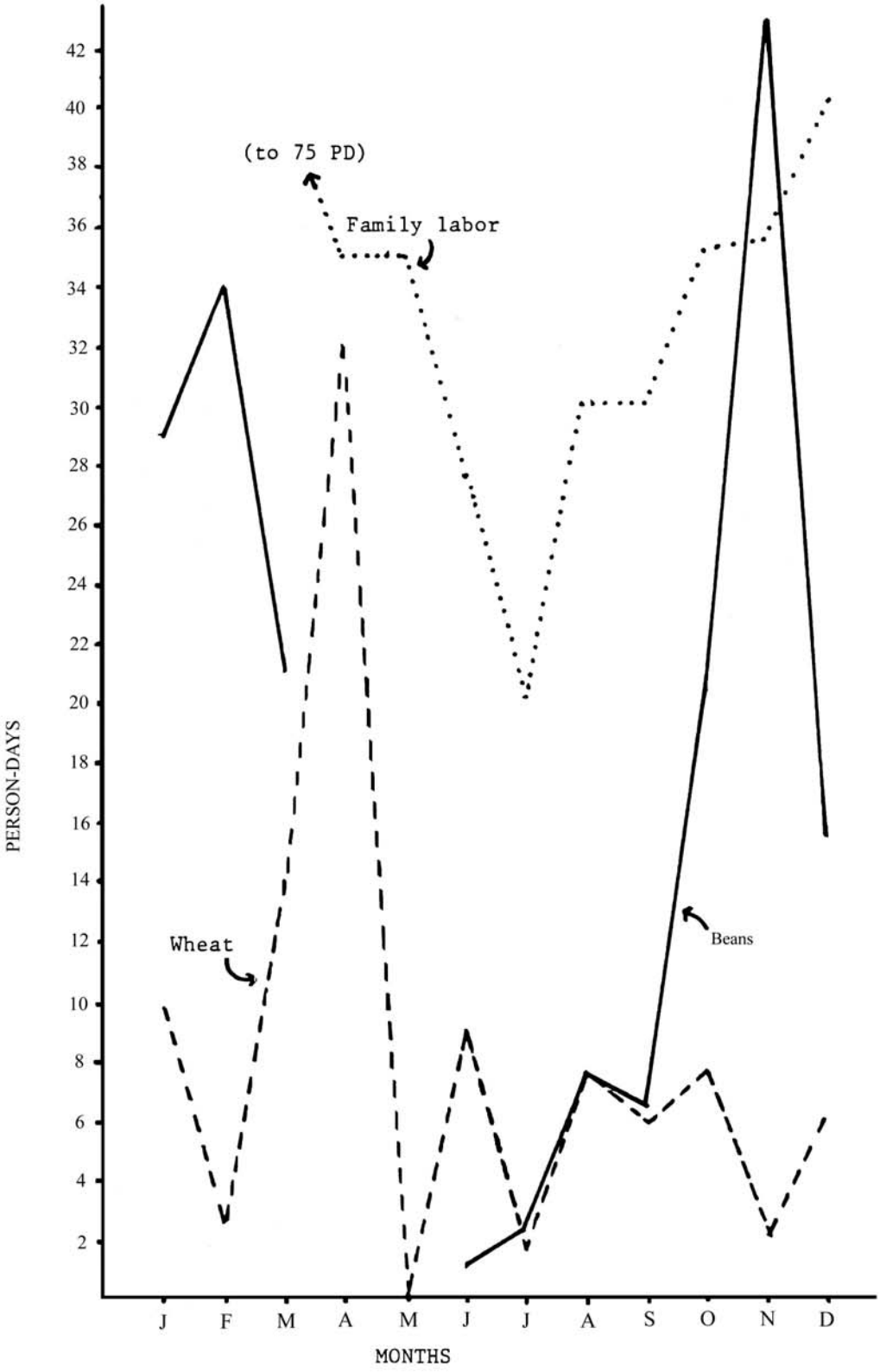


Fig. 3. Monthly labor use in bean and wheat crops compared with effective family labor availability.

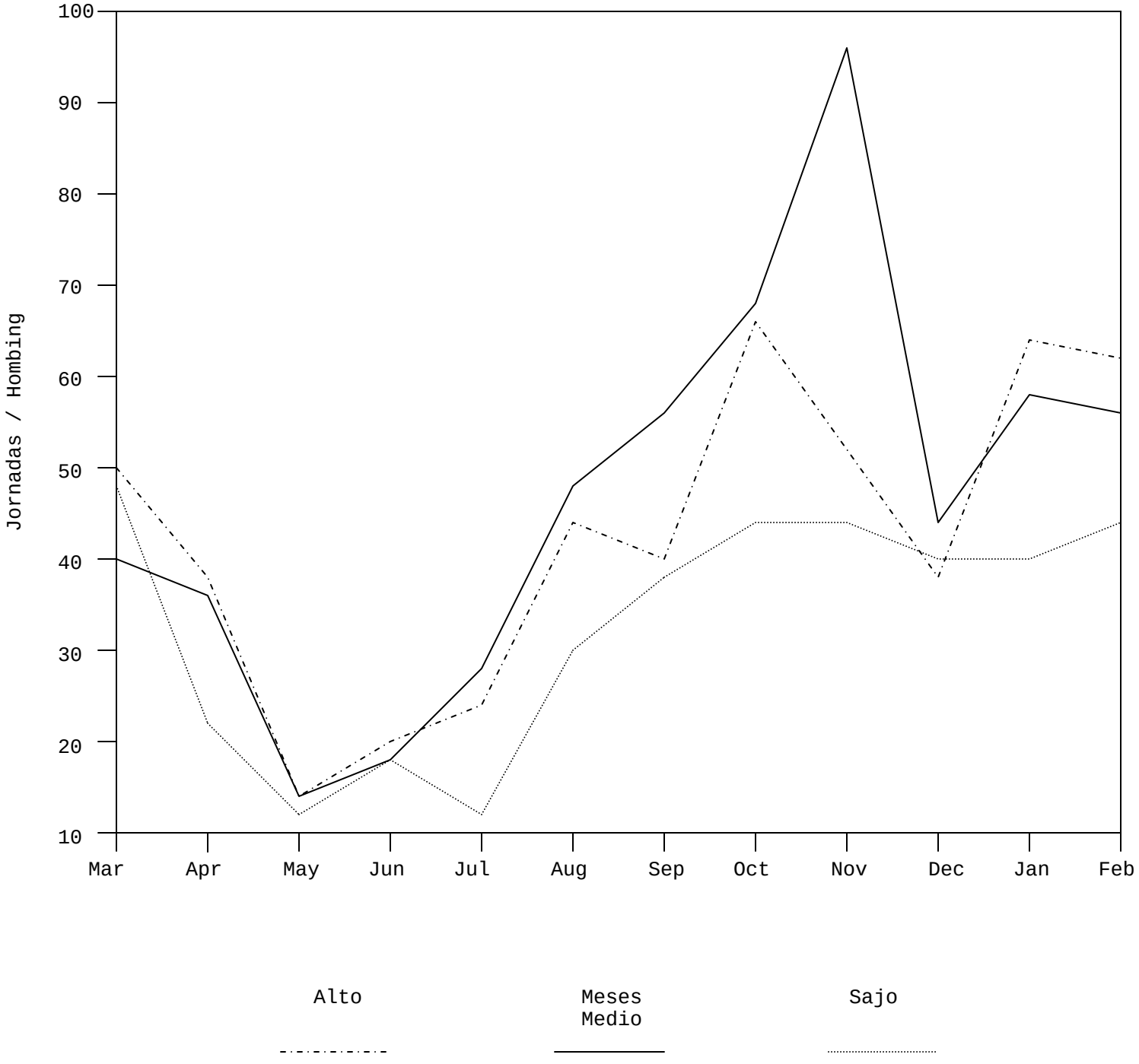


Fig. 4. Monthly labor use.

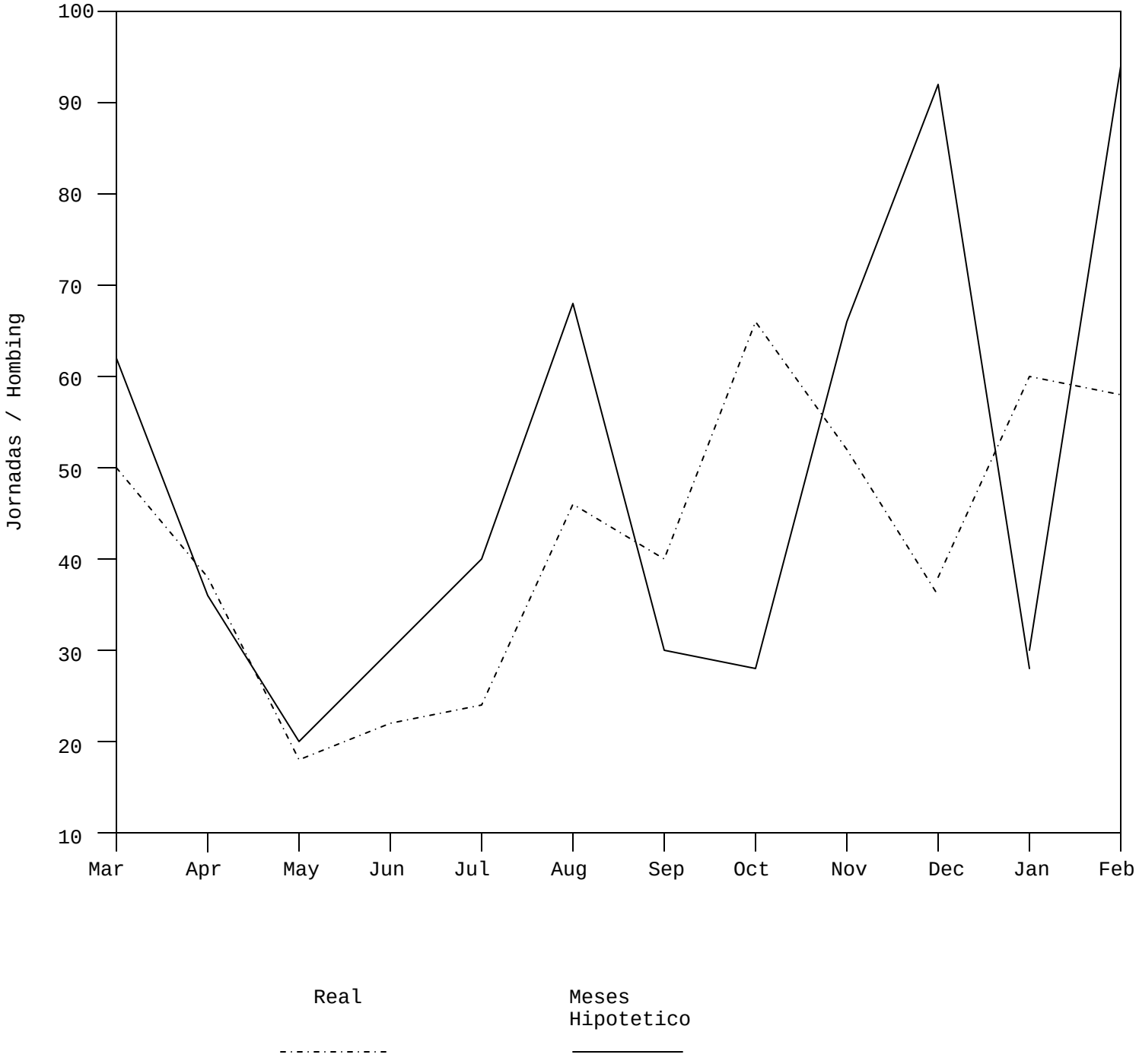


Fig. 5. Actual and hypothetical labor use.

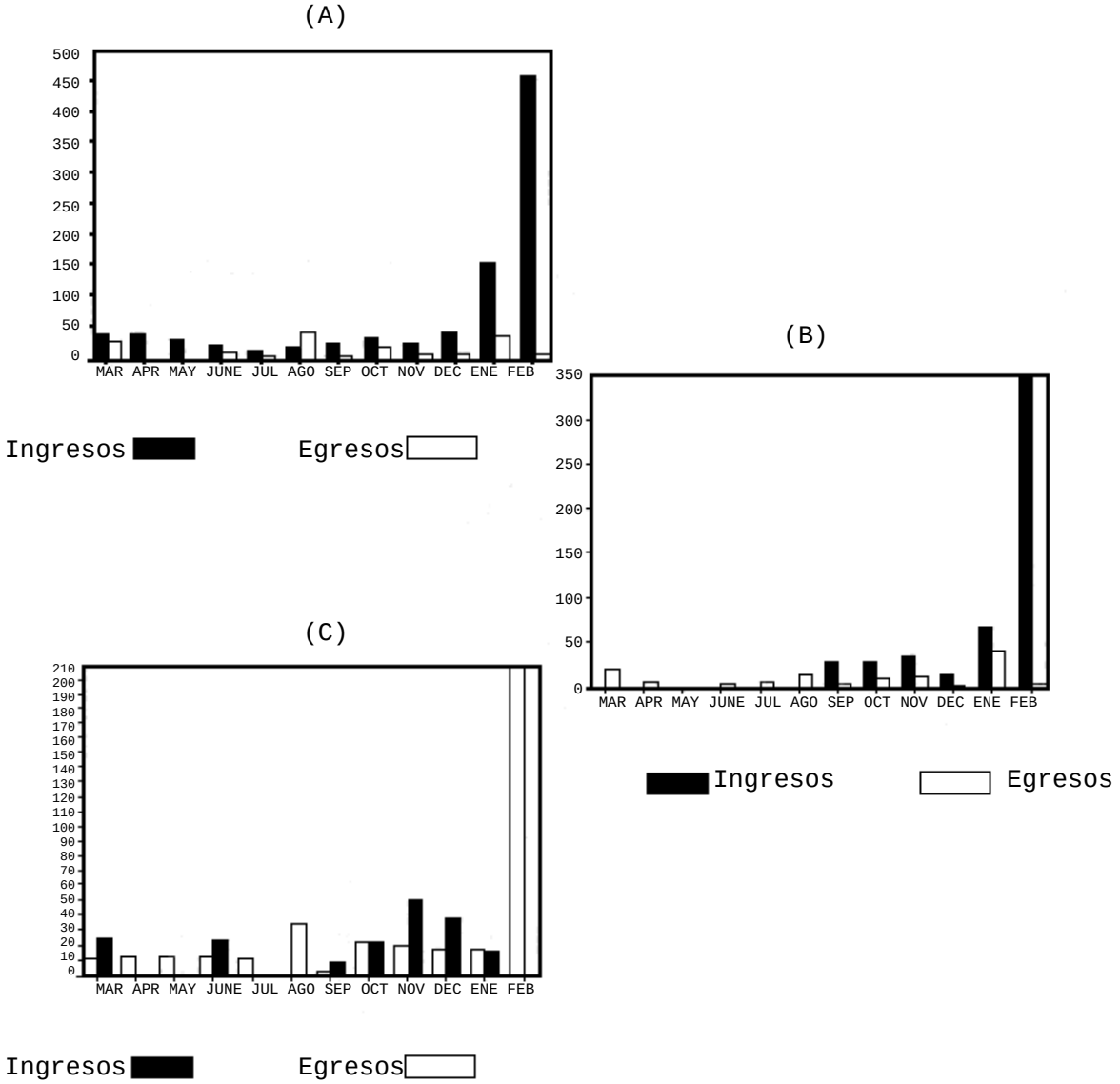
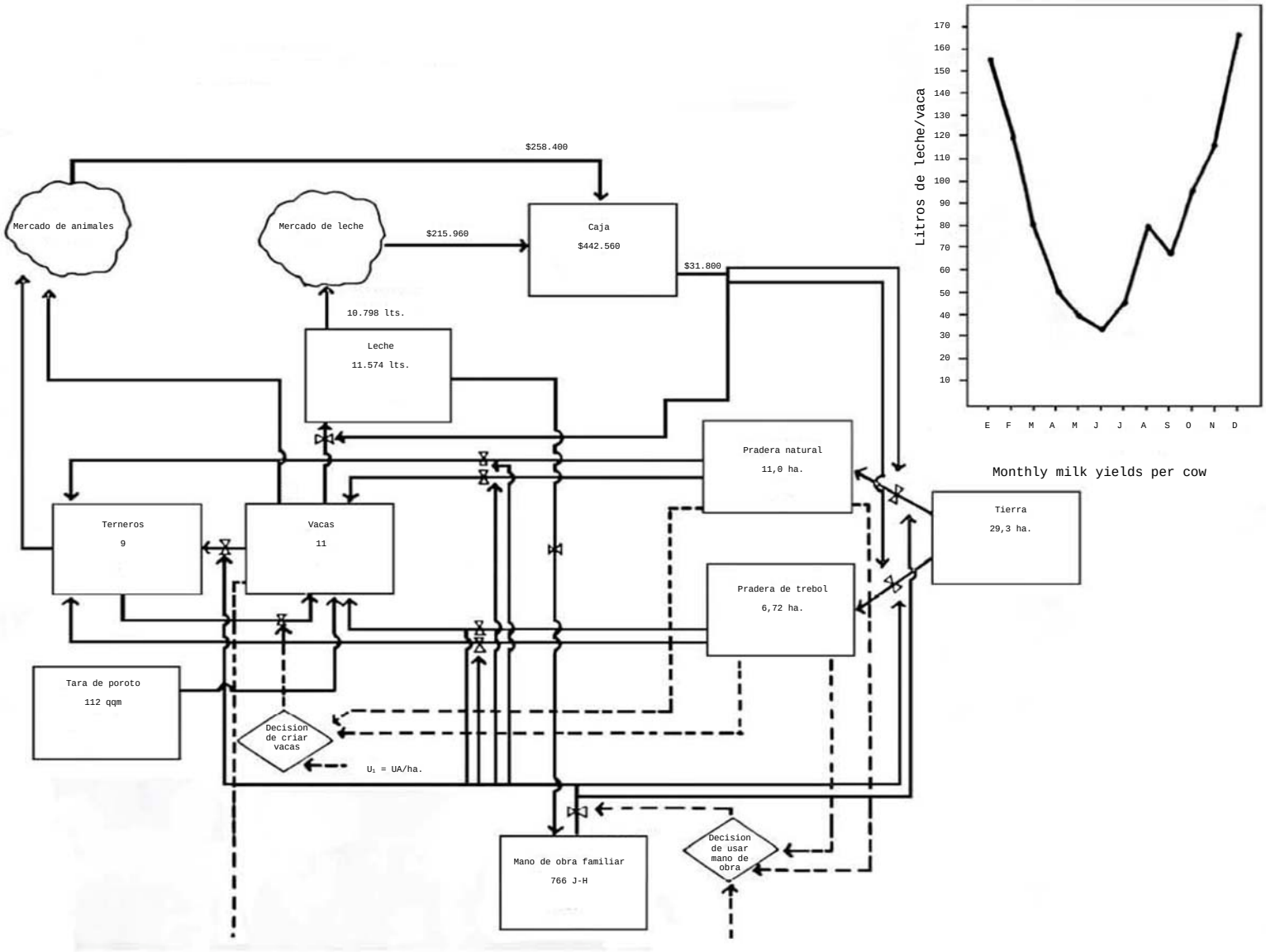


Fig. 6. Monthly income and expenses:
(a) high stratum
(b) medium stratum
(c) low stratum

Fig. 7. Flow diagram of the livestock subsystem.
Mean values of three strata, 1985/1986.



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