PN-AAN-941
ISN 32622

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BY
DEREK BYERLEE, LARRY HARRINGTON, AND
DONALD L. WINKELMANN

Reprinted from
AMERICAN JOURNAL OF AGRICULTURAL ECONOMICS
Vol. 64, No. 5, December 1982

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Since 1978, when several publications (e.g., CGIAR, Norman) drew attention to Farming Systems Research (FSR), interest in FSR has increased dramatically. This is reflected in a growing number of publications and workshops on the theme and a sharp increase in the commitment of resources to its implementation in developing countries (Byerlee et al.; Zandstra et al.; Shaner, Philipp, Schmehl). At the same time there are rising expectations about FSR's contribution to the effectiveness of agricultural research. While sharing this sense of optimism, we are concerned about the real possibility that expectations may be disappointed by hesitant, ponderous, and unfocused efforts.

The term "farming systems research" has been applied to a wide variety of activities. In its broadcast sense, FSR is any research that views the farm in a holistic manner and considers interactions in the system (CGIAR). As such, "there is little activity concerned with agricultural and rural development which cannot claim some relationship with FSR, however tenuous" (Gilbert, Norman, Winch, p. 31). This explicit recognition of the importance of interactions in the farming system we will define as the farming systems perspective (FSP).

Research with a farming systems perspective can have various objectives ranging from increasing the body of knowledge about farming systems to solving specific problems in the farming system. Expectations are highest in its problem-solving role where the aim is to increase productivity of the farming system by generating new technologies appropriate for farmers. This research is often further divided into location-specific research with a short-run objective of developing improved technologies for a target group of farmers and research conducted with a longer time perspective to overcome major, widespread constraints in farming systems.[1] We will argue that these two approaches are part of an integrated research system in which area-specific research provides the basis for defining longer-term research priorities.

Further confusion is caused by the fact that farming systems research is often defined in terms of a specific methodology, on-farm research, where farmers are involved in identifying potential technological improvements that are then tested under their conditions. On-farm research, however, need not be based on a farming systems perspective while research on experiment stations sometimes is. Hence, it is useful to distinguish between concept (FSP) and method (the conduct of research with farmer involvement at each stage).

In this paper, we discuss that subset of FSR which has the following characteristics: (*a*) It aims to generate technology to increase resource productivity for an identified group of farmers, especially in the short term. (*b*) It is conceptually based on a farming systems perspective. (*c*) It uses on-farm research methods. We shall refer to research with these characteristics as on-farm research with a farming systems perspective (OFR/FSP). Taking the viewpoint of national agricultural research programs, we argue that this specific subset of research activities should receive priority in efforts to improve the effectiveness of agricultural research. We then highlight methodological issues in OFR/FSP, especially those most relevant to agricultural econo-

The authors are economists with the Economics Program, CIMMYT, Mexico.

They are grateful to many of their colleagues in CIMMYT for helping to formulate and clarify ideas developed in this paper. However, views expressed are not necessarily those of CIMMYT. The authors also thank E. Crawford, J. Dillon, C. Eicher, S. Franzel, E. Kellogg, S. Johnson, and W. Shaner for helpful comments on an earlier draft.

[1] These are referred to as "downstream" and "upstream" FSR by some authors (e.g., CGIAR). We disagree with this terminology—"downstream" is hardly consistent with the "bottom-up" philosophy of FSR. We are also confused by the definition of "upstream" research. Gilbert, Norman, and Winch limit it to research to overcome major resource constraints, such as soil moisture conservation or fertility maintenance.

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mists. The review is by no means complete but rather emphasizes problems encountered by national research programs concentrating on crop enterprises (Bernsten).

Research Strategy in National Programs

The Need for a Farming Systems Perspective

Many small farmers in developing countries make decisions in an environment that leads to complex farming systems.[2] Some of the most important elements leading to this complexity are:

(*a*) a long growing season, especially in tropical areas, which increases the range of potential crops and the possibilities of multiple cropping, including intercropping;

(*b*) unreliable input and output markets, uncertain climate, and low farm incomes, which increase the importance of risk in farmer decisions;

(*c*) farm households that tend to consume what they produce because of high marketing margins and price variability, contributing several additional elements to the objective function, such as production of preferred foods and a balanced seasonal distribution of food supplies;

(*d*) family labor as an important factor share (overall low productivity of labor combined with seasonal labor shortages often being an important influence on the farming system);

(*e*) resources employed by the farm household which often exhibit considerable heterogeneity, even within the household (e.g., land may be differentiated by quality, or labor is provided by males, females, and children).

These considerations make for complex farming systems with a wide range of enterprises and even a range of production practices for a given enterprise, such as the use of more than one variety or planting date for a crop. Complexity in most cases results from (*a*) direct physical interactions between production activities generated by intercropping and crop rotation practices, (*b*) competition and complementarity in resource use between different production activities, and (*c*) the multiple objective function of the farm household. These interactions, from both biological and socioeconomic sources, underlie the need for a farming systems perspective and a multidisciplinary approach in research on improved technology.

The Role of On-Farm Research Methods

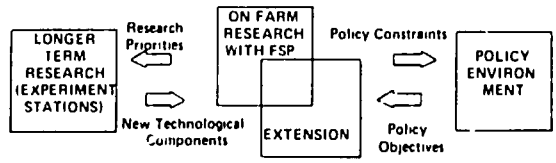
Small farmers in some developing countries have not adopted technologies recommended by research programs, often because these technologies are not consistent with their circumstances. Traditionally organized along disciplinary or commodity lines and without involvement of social scientists, agricultural research frequently has lacked an FSP. Moreover, this research typically has been conducted on research stations under conditions that are not representative of farmers' fields and with little or no farmer involvement.

On-farm research methods offer an opportunity to overcome these deficiencies because direct communication of a multidisciplinary research team with farmers increases understanding of the farmers' decision-making environment and enables identification of technological alternatives more consistent with that environment.[3] Finally, experiments under farm conditions add assurance that resulting technologies will meet farmers' needs.

Indeed, a program of OFR/FSP can be seen as central to the research system (see figure 1). Research with a longer-term perspective, usually conducted on experiment stations, can be closely tuned to farmer problems identified in on-farm research. Research and extension can be integrated, particularly in the verification and demonstration of technological components (Palmer, Violic, Kocher). Finally, an integrated research-extension system is part of a wider policy environment. Policy goals can

[2] Although we emphasize small farmers in this paper, we feel that OFR/FSP also has substantial value in commercial agriculture. Pay-offs may, however, be less because of less complex farming systems and because commercial farmers may already have considerable influence on research decisions.

[3] In this paper, technology refers to the totality of practices used to produce a crop, while a technological alternative is a specific practice or input, such as a specific weed control method.



Source: Adapted from Byerlee, Collinson et al.; and Palmer, Violic, and Kocher.

Figure 1. Overview of an integrated research program

guide selection of target groups of farmers for the research program. On-farm researchers with a first-hand understanding of farming systems and knowledge of biological responses to alternative practices under farmer conditions are in a unique position to identify policy constraints and promote changes in the policy environment to complement technological change.[4]

The reorientation of an agricultural research system so that it is firmly based on OFR/FSP requires changes in research structures, organization and incentives (e.g., see Moscardi et al.). Moreover, programs must be established within existing scarce research resources by researchers with little practice in applying on-farm research methods or a farming systems perspective. Hence, methods used in OFR/FSP must be efficient in terms of resources, especially human resources, but also financial resources and data processing facilities. (To some extent the increasing availability of microcomputers will help overcome the constraint on data processing.) Moreover, these programs initially tend to have only the partial support of research administrators, so convincing results are needed early in research programs to ensure continuation and full integration into the research system.

An Efficient Strategy for OFR/FSP

There is a potentially serious inconsistency between our advocacy of a farming systems perspective as a holistic view of an often complex farming system and the use of research methods which are cost effective and emphasize rapid results. However, small farmers with capital scarcity, risk avoidance objectives, and a cautious learning process rarely make drastic changes in their farming system. Rather, they proceed in a step-wise manner to adopt one and sometimes two new inputs or practices at a time.[5] Hence, because of resource constraints of both national programs and their farmer clientele, an efficient research strategy should focus on a very few—perhaps two to four—research opportunities that offer potential to increase resource productivity in a way acceptable to farmers. The identification of these research opportunities and their development into technologies acceptable to farmers can and should be done using a farming systems perspective.[6] However, an OFR/FSP program should not seek as an immediate objective the development of completely new farming systems since farmers rarely adopt farming systems (Collinson 1981).[7] Rather, in the long run, a new farming system may evolve as the result of a series of discrete changes to the existing system.

OFR/FSP programs are most efficiently implemented for identified strata or relatively homogenous groups of farmers. The essential criterion for distinguishing strata is the extent to which final technological recommendations are affected. Hence, we have proposed the concept of a recommendation domain (RD) as a group of farmers with roughly similar practices and circumstances for whom a given recommendation will be broadly appropriate. It is a stratification of farmers, not area; farmers, not fields, make decisions on technology. Socioeconomic criteria may be just as important as agroclimatic variables in delineating domains. Thus, resulting domains are often not amenable to geographical mapping because farmers of different domains may be interspersed in a given area.

OFR/FSP programs rarely have sufficient resources immediately to cover all RDs. Rather, initial research will focus on those domains that conform to policy objectives, such as increased food production or reducing rural income disparities as well as those offering a good probability of demonstrating success in the short term. These RDs can then act as building blocks for training additional personnel in OFR/FSP and convincing research administrators of the value of the approach.

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[4] Researchers are often faced with the dilemma about which policy-related variables to consider variable and which to consider fixed. For example, if a promising technological alternative is dependent on an input not available to farmers, researchers may want to direct attention to providing information to policy makers on the benefits of making the input available.

[5] It is sometimes assumed that OFR/FSP can make significant gains by a reallocation of existing resources, such as changing plant spacing or extra weeding, without introducing new inputs to the system. We believe this is an exceptional case and in fact is contrary to the systems perspective of a rational farmer.

[6] This process will often result in research opportunities being related largely to one crop in the system, usually a major resource user. Many programs also have mandates for research on a specific crop, so researchers can select regions with high probability that research on that crop will increase system productivity.

[7] Development of new farming systems may be appropriate where there is a drastic change in the farmers' external environment, such as the introduction of irrigation or a colonization program.

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Selected Issues in Data Collection and Technology Design

Economic Principles in Data Collection

A program of OFR/FSP can be regarded as a process of generating information for particular users. Farm surveys are undertaken to provide information to focus experiments which, in turn, provide information for making recommendations to farmers. The design of an efficient data collection strategy can be guided by common principles of the economics of information, including the following:

(*a*) Information on some variables will have relatively more value to the user, and this justifies allocating more resources to obtain better information on these variables.

(*b*) Users of information have time preference functions that discount the value of future information relative to present information.

(*c*) There are diminishing returns to additional information on specific variables that must be balanced against increasing costs, both in resources (e.g., a larger sample size) and time.

(*d*) An efficient process employs a sequential decision strategy in which information available at one point in time is used to make decisions on whether, how much, and what type of information should be generated in the future.

The overall data collection strategy therefore should be a sequential process that begins with obtaining, quickly and cheaply, some information on the variables needed for an initial understanding of the farming system. This information is then used to guide further data collection on fewer, more important variables. Finally, the process focuses on those few variables related to key research opportunities, to identify and prescreen technological alternatives for inclusion in experiments. At each stage, the value of additional information is judged against its costs including the opportunity cost of time spent gathering additional information.

Choice of Data Collection Techniques

A data collection strategy may consist of one or more data collection techniques, each defined by specific characteristics. Our experience indicates that an efficient data collection strategy begins with collection of secondary information and is then followed by an exploratory survey, a verification survey, and on-farm experiments with characteristics shown in table 1. It is a sequential process in which information becomes more detailed and focused at each subsequent step in the process.

We increasingly depend on the exploratory survey to understand the farming system rapidly and identify key research priorities. The essential characteristics of this technique are its relatively unstructured approach and the high degree of researcher participation in field interviews and observations (see table 1, also Collinson 1981, and Hildebrand). A multidisciplinary team of researchers interviews farmers in an informal and iterative manner, guided by a systems perspective of farmer decision making and oriented by a list of topic themes. Meanwhile, the biological dimensions of crop or livestock production are observed in farmers' fields. The whole survey is usually completed in two to three weeks in a given recommendation domain.

The exploratory survey is itself a sequential technique. Information is analyzed and evaluated on a daily basis by the research team to make decisions on further data collection. Initially, researchers try to obtain a broad description and understanding of the farming system. They then focus on research opportunities for increasing productivity and, finally, the assessment of possible technological alternatives to be included in on-farm experiments.

A major issue in using the exploratory survey is the extent to which it provides sufficient quantitative information. Formal statistical testing of hypotheses is limited, because a random sampling method is not used and because sample size is often small, since researchers themselves do the interviewing. However, where variability in the study area is not high, this sampling error is often less than the measurement error encountered when enumerators are used to administer questionnaires to a larger randomly chosen sample.

Quantitative information also may be useful in conveying conclusions to other users. However, given that the main users of the information are the researchers themselves, for planning their experimental program, the need for quantitative data is greatly reduced. Nonetheless, if the research team wishes to convey information to other users, such as

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Table 1. Characteristics of Data Collection Techniques Usually Employed by CIMMYT

Characteristic	Type of Data Collection Technique[a]		
	Exploratory Survey	Verification Survey	On-Farm Experiments
Number of variables included	Initially very large, but narrowing as the survey proceeds and as accumulated data is analyzed daily.	Small, focusing only on key variables determined in the exploratory survey to be important for technology design.	Very small–includes two to four priority factors identified in the farmer surveys.
Degree of structure	Relatively unstructured, with questions formulated specifically for each interview, depending on accumulated information and the particular farmer.	Structured questionnaire is used with specific questions asked in a given sequence; exploratory survey results used to formulate relevant questions.	Structured use of common experimental designs.
Researcher field participation	Researchers conduct interviews and record and analyze data.	Enumerators often employed to conduct interviews under researcher field supervision.	Researchers conduct and observe experiments.
Extent of multidisciplinary cooperation	Very high, with technical and social scientist working as a team.	Questionnaire designed by multidisciplinary team but implemented by economist.	Experiments designed by multidisciplinary team, but implemented by agronomist.
Degree of observation	Includes observation of farmers' fields and practices, especially biological dimensions of crop production.	Usually based only on interviews, sometimes with field observation of a special problem.	Crop responses are directly observed and measured.
Frequency of data collection	Usually only one visit to each farmer.		Multiple visits to observe experiments and farmer practices and conduct informal farmer interviews.
Degree of quantification of variables	Emphasizes qualitative data, but with sufficient quantitative measurements to prescreen technological alternatives.		Quantification of yield response to technological alternatives.
Estimation of confidence intervals on variables or hypotheses	Only subjective confidence intervals possible. Random sampling not used, but efforts made to sample variation.	Random sample allows formal statistical tests.	Selection of representative farmers based on verification survey. Replication in and across sites allows statistical tests.

[a] The use of information from secondary sources is also important but not included here.

experiment station researchers or policy makers, quantitative data often will be more effective.

For these reasons, we generally recommend that an exploratory survey be followed by a well-focused "verification" survey using a short, structured questionnaire (sometimes only one to two pages long) and a random sample (see table 1). Following our principle of sequential data gathering, this decision should be made on the basis of the results of the exploratory survey. In our experience, the verification survey has not significantly changed our conclusions on the broad outline of an experimental program. By allowing formal testing of hypotheses, however, it does provide greater confidence in these conclusions. This is especially so in selection of recommendation domains in target areas with considerable variability in agroclimatic factors and farmer type and in quantifying the characteristics of a representative farmer for each domain. Note that even in the verification survey, the emphasis is on a low cost method that provides information and analysis in a few weeks.

A further important issue in the collection of quantitative information is the role of multiple-visit surveys over a cropping cycle or year to collect data for labor inputs and outputs by crop. We argue in the next section that detailed labor data are needed only on changes in labor inputs associated with the introduction of a new technological alternative. Likewise, one of the major purposes of on-farm experiments is to obtain accurate output information. Hence, there is little justification for conducting a data-intensive, multiple-visit survey

before beginning experimentation. Such a survey might be conducted with farmer cooperators in the experimental stage (e.g., Hildebrand), but even here we emphasize participant observation techniques in which researchers informally interview collaborating farmers and their neighbors on each visit to the experiment to obtain, over time, a better understanding of the farming system (Tripp).

Technology Design

Possibly the area where methodology is least developed is in the use of information on farmer circumstances to select the technological alternatives for experimentation. Technology design consists of identifying important opportunities and then prescreening technological alternatives for each research opportunity in light of farmer circumstances.

Various approaches have been used to identify major avenues for research. Some programs focus on system interactions, some on resource constraints, and some look for enterprises with low returns to particular factors. However, increases in productivity will require the introduction of new inputs, new practices or new crops to increase yields, reduce costs or risks, or increase cropping intensity. Hence, in the final analysis, it is necessary to focus on identifying possible leverage points for biological research. These suggest research opportunities which, in turn, give rise to hypotheses about experimental treatments. Each treatment is then screened for suitability against the background of farmer circumstances, emphasizing system interactions, input availability, and risk and profit considerations in identifying priority research opportunities. This process is best begun in the exploratory survey where the multidisciplinary team, through informal conversations with farmers and merchants along with field observations, can formulate rapidly and informally test hypotheses.

We have argued that (*a*) existing farming systems usually reflect a rational use of resources given farmers' objectives and experiences, and (*b*) a research strategy should introduce changes to this farming system in a step-wise manner. Hence, screening of technological alternatives need only focus on changes in key system variables rather than modeling of the whole farming system.

In our experience, checks on the appropriateness to farmer circumstances of a given set of technological alternatives can be performed best by constructing a simple matrix with the technological alternatives on one axis and important system variables identified in the exploratory survey on the other. These system variables might include profitability, risk, labor use in the peak season, food supplies in the "hungry" season, or cash expenditures. Brief qualitative or quantitative statements on the impacts of each alternative on each variable form the body of the matrix. With this matrix the researchers can usually judge the few treatments that offer the highest probability for increasing productivity and being accepted by the farmers.

Partial budgeting of changes in costs and returns is a useful tool for quantifying the effect of a technological alternative on profitability. It avoids the need to measure profitability in each enterprise or for the whole system. Whole farm models, such as those based on linear programming, are normally not necessary for this task and indeed are usually not suitable given the time and skill constraints of a local field research team.

FSR, Farm Management Research, and the Training of Economists

Given our disciplinary training, there is a natural tendency for economists to employ a farm management approach in OFR/FSP. We believe that quite a different approach is needed. Current farm management texts emphasize the use of input-output information to improve resource allocation within the farm, especially the comparison of the profitability of alternative farm enterprises.[8] In much OFR/FSP we are interested in developing improved technologies for farmers on the basis of an understanding of current farming systems. We have argued that such an understanding requires a much broader systems perspective that integrates biological dimensions of production, heterogeneity in resources, risk factors, and the relationship of production and consumption decisions. Furthermore, we have stressed that this understanding is best obtained by direct researcher-

[8] Johnson has argued that farm management approaches of an earlier period in the U.S. have parallels with the current FSP in research.

farmer contact in the field. In contrast, the farm management approach relegates the understanding of the farming system to *ex post* data analysis through whole farm modeling.

Data collection techniques developed for farm management research are also of limited applicability in OFR/FSP. Data are obtained from structured questionnaires administered by enumerators, often in frequent visits, with questions guided by an input-output framework. The cost of this information is often high, and analysis is frequently delayed by bottlenecks in data processing so that timeliness is sacrificed. Moreover, the value of the information obtained may be relatively low in a program aimed at generating improved technologies. For example, when seasonal labor is a constraint, researchers can obtain a good understanding of the implications of this constraint for introducing new technological alternatives by asking farmers about their perceptions of busy periods, the operations performed in these periods, those that are not performed in a timely manner, and the availability of outside labor sources or labor-saving techniques. This type of information, combined with field observations that look for problems reflecting a labor shortage, e.g., late planting or untimely weeding, provide better information for technology than will analysis of detailed labor flow data.

Hence, one of the major constraints to effective participation of economists in programs of OFR/FSP will be their training. Training of economists needs to emphasize (*a*) a much broader systems perspective on farmer decisions than is provided by current farm management and production economics approaches, (*b*) an acquaintance with biological issues in plant growth and animal husbandry, and (*c*) a knowledge of farm survey methods including informal approaches. This training, whether in the university or a research institution, must be oriented strongly to field work that emphasizes direct interaction with farmers and technical scientists and the development of skills necessary for farmer interviewing and participant observation.

Conclusions

The importance of broad-based technological change in agriculture for promoting rural development and welfare, and the need to explore "bottom-up-farmer-first" means of achieving this change, is ample justification for the current interest in farming systems research. However, the variety of activities currently being conducted in the name of FSR is causing substantial confusion and, unless clarified, will lead to disenchantment with the approach among donor agencies and research administrators.

We have argued here from the perspective of national research programs that the main objective of farming systems research should be to help solve the problem of increasing productivity of the farming system through on-farm research which recognizes important interactions in the farming system. Of course, variation in resources and maturity of national programs and in farming systems justifies some differences in approach. However, we consider that a careful specification of research objectives within the available resources and time frame and a critical examination of information needs at each step of the way should lead to a convergence of research strategies and methods being employed in the name of farming systems research. The scarce resource situation of national programs and the established step-wise adoption behavior of farmers lead us to conclude that such research should be highly focused on only a few priority research opportunities in the system.

The need to develop efficient research methodologies should be a natural concern of economists. Unfortunately, economists have been among the worst offenders in promoting long, detailed, and unfocused studies of the farming system. The economist potentially can play an important role in helping to understand farming systems and in identifying research opportunities, but the objective should be to establish an on-farm experimental program quickly. The conventional tools of our trade based on standard farm management techniques have limited relevance in this role. As an alternative, we have proposed that data collection be designed as a sequential process, with information becoming more detailed and focused at each subsequent step in the process. Active field participation of researchers and informal contacts with farmers are also important elements of the strategy. Research opportunities are identified and screened through the researchers' first-hand understanding of the farmers' environment and the use of simple tools to evaluate changes in the system rather than by whole farm modeling.

As measured by farmer acceptance of technological components developed in OFR/FSP programs, successful results are beginning to emerge (see Moscardi et al., Martínez and Sain, Hildebrand). Even with more attention to efficient research methods, however, new recommendations do not usually emerge until three years after initiation of research, and widespread adoption of the technologies generally will not occur before five years from initiation. An even longer time horizon is more realistic for full-scale institutionalization to provide a continuous flow of benefits over the long term. Hence, donor agencies and research leaders must have realistic expectations about OFR/FSP. However, agricultural research is by nature a long-term investment and OFR/FSP offers not only the opportunity for relatively quick pay-offs and a continuing flow of research output but also the potential to focus the entire research system more closely on the needs of the farmer.

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