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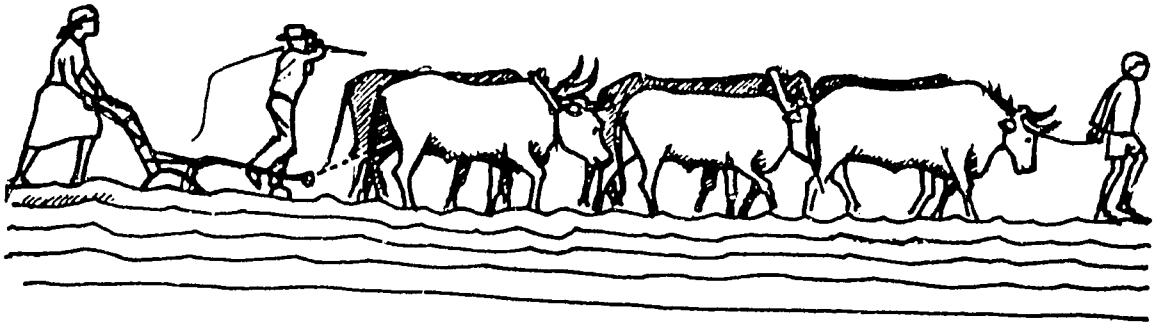
AGRICULTURAL TECHNOLOGY IMPROVEMENT PROJECT (ATIP)

Farming Sytems Research Handbook for Botswana

ATIP RP 3



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AGRICULTURAL TECHNOLOGY IMPROVEMENT PROJECT

ATIP

FARMING SYSTEMS RESEARCH HANDBOOK FOR BOTSWANA

ATIP RP 3

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PREFACE

For many years, the Farming Systems approach has been applied by various teams throughout Botswana. Until fairly recently the approach has tended to evolve independently within these teams with little view to coordinating efforts. However, these teams are now under the auspices of the Department of Agricultural Research (DAR) which calls for a more consolidated strategy with respect to the methodological aspect of farming systems research.

In response to this need to develop a more unified approach, this handbook offers guidelines on how to conduct farming systems research within Botswana. These guidelines are a culmination of ideas and strategies developed not only by the Agricultural Technology Improvement Project (ATIP), but also from input from the other farming systems teams, the Molapo Development Project (MDP) and the Farming Systems Southern Region (FSSR).

This handbook is not meant to be a comprehensive document, but rather a practical guide, providing examples from Botswana, to enable farming systems practioners to successfully carry out farming systems research within this harsh climatic zone. It outlines the methodology and implementation strategies necessary to deal with the many unique features which make up Botswana. It is anticipated that improvements in the various techniques, discussed in the handbook, will develop as a result of additional experience gained by the farming systems research practioners.

The handbook consists of two separate documents. ATIP RP 3 contains the actual guidelines. ATIP RP 4 provides examples of data collection and survey forms that have been used in farming systems research and which may be adapted for use by other farming systems personnel in Botswana. For those who would like more detailed information about the farming systems research approach, a list of recommended major references is provided in ATIP RP 3, and multiple copies of these references are available for long-term loan from the DAR library. Copies of ATIP RP 3 are readily available, while copies of ATIP RP 4 -- of which limited numbers were made -- can be found in the DAR library.

This handbook has been published with the approval of the Director of DAR, Dr. L. Gakale, the Chief Animal Production Research Officer, Dr. L. Setshwaelo, and the Acting Chief Arable Research Officer, Mr. O. Mmolowa.

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		8.1.3	8.1.4	8.1.5	8.3.1
		8.3.2	13.1.1	13.1.2	13.1.3
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		2.2.1	2.2.2	2.2.3	2.2.4
		2.2.5	2.3.1	2.3.2	2.3.3
		2.4.1	2.4.2	2.4.3	2.4.4
		2.5.1	2.5.2	3.1.1	3.1.2
		3.1.3	3.2.1	3.2.2	3.3.1
		3.3.2	3.3.3	3.4.1	3.4.2
		5.5.1	5.5.2	5.5.3	5.5.4
		7.1	7.2.1	7.2.2	7.2.3
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5.4.2	5.4.3	5.4.4	5.4.5
6.1.1	6.1.2	6.1.3	7.4.1
7.4.2	8.4.2	8.4.3	9.1.1
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9.2.1	9.2.2	9.2.3	9.3.1
9.3.2	10.1	10.2.1	10.2.2
10.3.1	10.3.2	10.3.3	10.4.1
10.4.2	10.4.3	10.5.1	10.5.2
10.5.3	10.5.4	10.6	11.1.1
11.1.2	11.1.3	11.2.2	11.3.1
11.3.2	11.3.3	11.3.4	11.3.6
11.4.1	11.4.2	11.4.3	11.5.1
11.5.2	11.5.3	12.1	12.2
12.3			

PART ONE:

INTRODUCTION TO THE FARMING SYSTEMS RESEARCH APPROACH

CHAPTER 1: INTRODUCTION

1.1 FARMING SYSTEMS PHILOSOPHY AND APPROACH

1.1.1 THE PROCESS OF AGRICULTURAL DEVELOPMENT

There are two ways to improve the productivity of farming families. These are:

(a). The development of ***relevant improved technologies*** by research (with inputs in terms of feedback from extension and farmers) and their dissemination via extension.

(b). The development of ***relevant policies and support systems*** by planning and their implementation by extension (development programs, etc).

Through increasing the productivity of farmers it is hoped that their incomes and standard of living (welfare) will improve.

To improve the productivity of farmers there are obviously a number of groups of people responsible for making sure this is possible. Table 1.1 indicates who these are and what are their roles and functions. Researchers and planners are responsible for developing relevant improved technologies and the appropriate policy/support systems. Farmers, with the help of extension workers, are actually responsible for improving the productivity of their farming systems.

TABLE 1.1: ROLES AND FUNCTIONS OF THE ACTORS IN AGRICULTURAL DEVELOPMENT

ROLE	FUNCTIONS	ACTORS
Implementers		Farmers
Supporters	Transmitters	Extension Staff/
	Input Provision	Development Agencies
Provide Potential Means	Technology	Research
	Policy/Support Systems	Planning

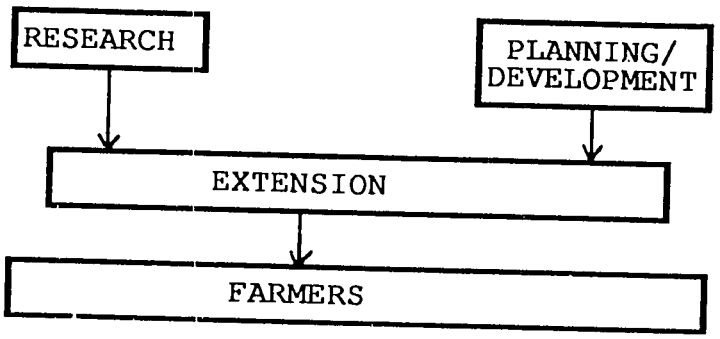
Therefore, close linkages between planners, researchers (on-station and on-farm), extension and development staff, and farmers are very important. Figure 1.1 illustrates the way in which these linkages can operate in practice. Unfortunately in many developing countries, until recently, the one-way "top-down" pattern shown in Figure 1.1A was still the most common. However, in recent years, many countries have decided that ideally linkages should be like those shown in Figure 1.1B. Therefore, there should be two-way interactive linkages between the various groups. However, the situation in many countries is that the link to the farmer ("top-down") is still stronger than from the farmer ("bottom-up"). This is shown in Figure 1.1C and possibly indicates what the current situation is in Botswana.[1]

Obviously strong linkages between these various contributors are of crucial importance. Growing realization of the critical importance of strong linkages has led, in recent years, to

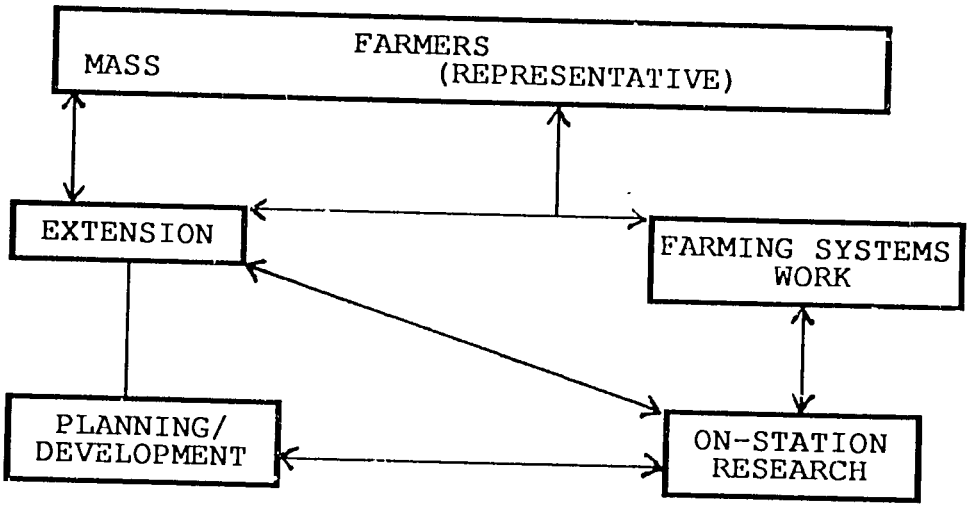
[1]. There can be a number a number of reasons why some of these linkages are not likely to be very strong -- see, for example Fresco and Poats [1986].

FIGURE 1.1: PROCESS OF AGRICULTURAL DEVELOPMENT

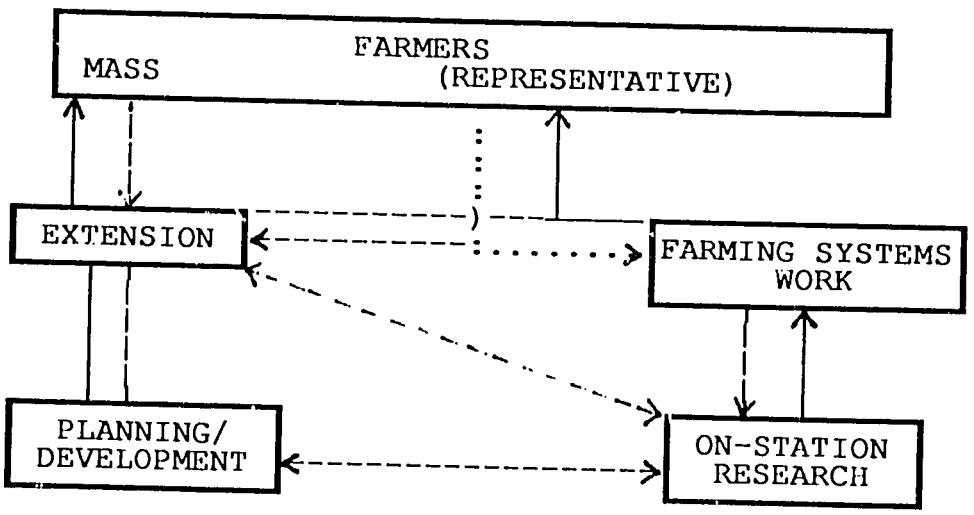
A. "TRADITIONAL" SYSTEM



B. "IDEAL" SYSTEM



C. "USUAL" SYSTEM



KEY: ——— INDICATE STRONG LINKAGES
- - - - - INDICATE POOR LINKAGES
..... INDICATE REASONABLE LINKAGES

Source: Norman [1989B].

an increasing emphasis on farming systems research (FSR). This approach, involving working directly with the farmers, is a more "bottom-up" or "micro to macro" orientation, compared with the more "top-down" or "macro to micro" orientation of research work that stans with the experiment station or the upper levels of planning ministries. Figure 1.1B indicates that farming systems work can help in making linkages amongst the various groups stronger. In doing so it helps in the process of improving productivity, but does not produce a product by itself.

As mentioned above, relevant improved practices/technologies and policy/support systems are needed to bring about increased agricultural productivity. Decisions on which strategy is to be emphasized to increase agricultural productivity will depend on circumstances. For example, if there is no technology that will ensure an economic return to fertilizer, there will be little value in concentrating on developing an input distribution system which makes fertilizer available to farmers. Therefore, the linkage or complementary nature between developing and disseminating relevant improved technologies and policy/support systems needs to be constantly borne in mind, if the agricultural development process is to proceed efficiently.

1.1.2 DEFINITION OF A FARMING SYSTEM

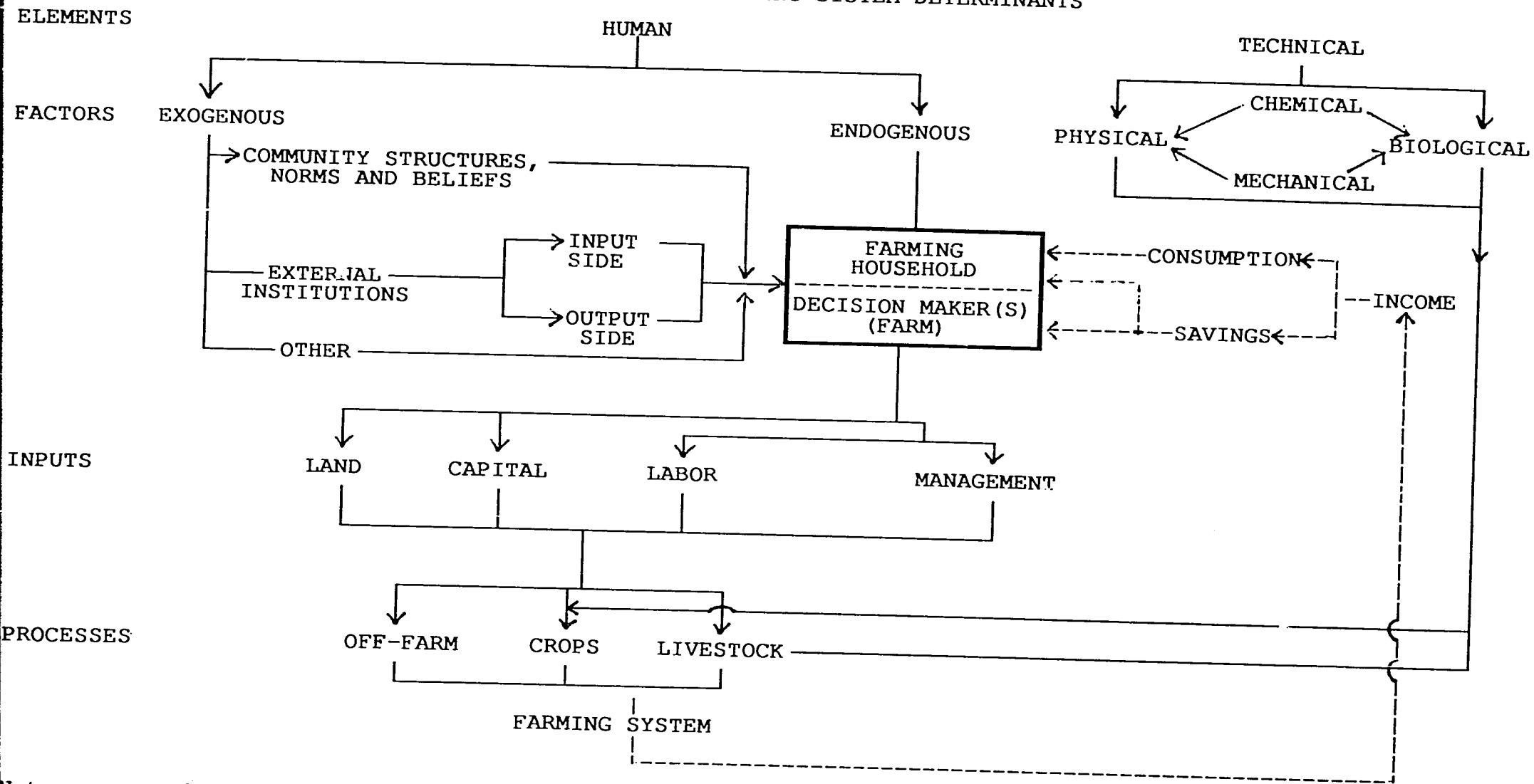
To design appropriate or relevant ways of helping farmers it is essential to understand the conditions under which farmers are operating. They have, in fact, very complicated farming systems. Figure 1.2 shows some of the factors that have an influence on what the farming system will be. The operator of the farming system is the farmer or the farming family -- since to farmers, the way in which they earn their living, and the economic, social and cultural well-being of their households is closely linked and cannot be separated

The members of the farming household have three basic types of inputs: land, labor and capital. Management involve allocating these to three different processes, that is, crops, livestock, and off-farm enterprises. In making decisions on how to allocate their inputs in producing one or more products, farmers have to make some difficult decisions. An important consideration in this decision will involve using their knowledge, to come as close as possible to fulfilling the goal(s) they are striving for. The goal(s) they are striving for may vary from farmer to farmer, e.g., maximizing their income, producing enough food to feed the family, etc. For many of the farmers we are working with, most are likely to want to maximize their incomes once they have made sure they are producing enough food to feed their family. The resulting combination of products (crop, livestock and off-farm enterprises) they are producing with their inputs, is the farming system. However, the extent to which the farming system fulfills the goal(s) they have chosen, will depend on the managerial skills of the farming family, and their ability to make good decisions in the allocation of inputs in a very uncertain agricultural environment.

Some parts of the environment that influence what the farming system will be are, however, outside the control of the individual farming family, thus causing uncertainty as far as the farmer is concerned. The "total" environment in which farming households operate consists of two parts: the technical (natural) element, and the human element.

(a). The technical element determines the types of, and physical potential of, livestock and crop enterprises. For example, in Botswana, the low level of rainfall makes it possible to grow sorghum, but not bananas, on rainfed land. Parts of the technical element include physical and biological factors. We often modify these to some extent through technology developments -- for example, increasing water availability through irrigation, improving soil quality by adding fertilizer, breeding for yield

FIGURE 1.2: SCHEMATIC REPRESENTATION OF SOME FARMING SYSTEM DETERMINANTS



Note: Broken lines represent the results of the farming system

Source: Norman, Simmons and Hays [1982].

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Date: March 25, 1990

stability during drought, etc.

(b). The farming system that actually evolves, however, is only part of what is potentially possible. The human element is important in determining what the actual farming system will be. The human element consists of two types of factors: exogenous and endogenous.

Exogenous factors (i.e., the social environment), are largely out of the control of the individual farming family. These factors will influence what the farming family can or are able to do, and can be divided into three broad groups:

i. Community structures norms and beliefs.
ii. External institutions, which on the input side includes extension, credit and input distribution systems, and on the output side includes markets.
iii. Other influences such as population density and location.

Endogenous factors, on the other hand, are those the individual farming household controls to some degree. These include the types of inputs mentioned earlier, that is, land, labor, capital and management. It is important to recognize that these resources vary among households and regions in Botswana. These vary on the basis of quantity and quality, both of which influence the performance and the potential of the system. In addition, these inputs or resources may or may not be owned by the household. Access to one or more of these resources may be on another basis of use (e.g., borrowing draft animals), which may limit or restrict the ease or intensity of use, and thus in turn affect the goals and performance of the farm family.

Nevertheless, it is the farming family which decides on the farming system that will emerge. This will, however, be influenced and sometimes constrained by the technical element and exogenous factors.

The farming system is obviously complex, and the results can vary greatly due to changes in the environment. These facts help explain why some technology thought to be relevant, often has not been adopted, or when it has, why the degree of adoption has varied widely. Not considering the human element in agricultural research has contributed to many so-called "improved" technologies being irrelevant.

1.1.3 DEFINITION OF FARMING SYSTEMS WORK

The primary objective of farming systems work (FSW) is to improve the well-being of individual farming families by increasing the overall productivity of the farming system in the context of both the private and societal goals, given the constraints and potentials imposed by the factors that determine the existing farming system. FSW involves using two complementary strategies (i.e., the development and dissemination/implementation of relevant improved technologies and policy/support systems) to improve agricultural productivity, mentioned earlier. We will use the term FSW to refer to both the technology and policy thrusts, and farming systems research (FSR) to signify the technology thrust. In fact, most farming systems work to date has concentrated on the technology thrust, and therefore FSR. Consequently most of the handbook concentrates on FSR.

In the literature, the term farming systems research (FSR), which usually refers to the development and dissemination of relevant improved technologies through on-farm research by working directly with farmers, has often been used loosely. There are programs called FSR that are not FSR, and there are programs not called FSR that are indeed FSR.

On-farm research itself is not necessarily FSR. To qualify as FSR it has to take into account interactions within the farming system. Shaner, Philipp and Schmehl [1982] and Dillon and Anderson [1984] have characterized FSR as research which:

(a). Views the whole farm as a system.
(b). Is conducted with a recognition and emphasis on the choice of priorities which reflect the whole farm.
(c). Research on a farm sub-system is legitimate FSR, provided the connections with other sub-systems are recognized and taken into account.
(d). Evaluation of research results explicitly take into account linkages between sub-systems.
(e). As long as the concept of the whole farm and its environment is preserved, not all the factors determining the farming system need to be considered as variable -- some may be treated as parameters or constants.

Therefore, even within its role in technology generation, confusion can be caused by a variety of approaches to FSW. These approaches can be summarized as FSW "in the large", "in the small" and "with a pre-determined focus" [Norman and Collinson, 1986]. A discussion on these is found in a later section in the handbook (Section 2.1).

Many individuals in the last 15 to 20 years have written extensively clarifying the concepts of FSW. This has led to more acronyms (e.g., FSR and D, FSR/E, FSAR and OFR/FSP, etc.). Unfortunately, at times this has led to more confusion as different people have given their own perceptions of what is FSW. However, there is no question that a certain convergence of ideas is taking place as a review of some of the major papers indicates.[2]

There are many ways of presenting a diagram of the process of farming systems research -- see, for example, Byerlee et al., [1980] and Zandstra et al., [1981]. However, the way we usually show it in Botswana is given in Figure 1.3. There are four stages in the farming systems research process. These are as follows:

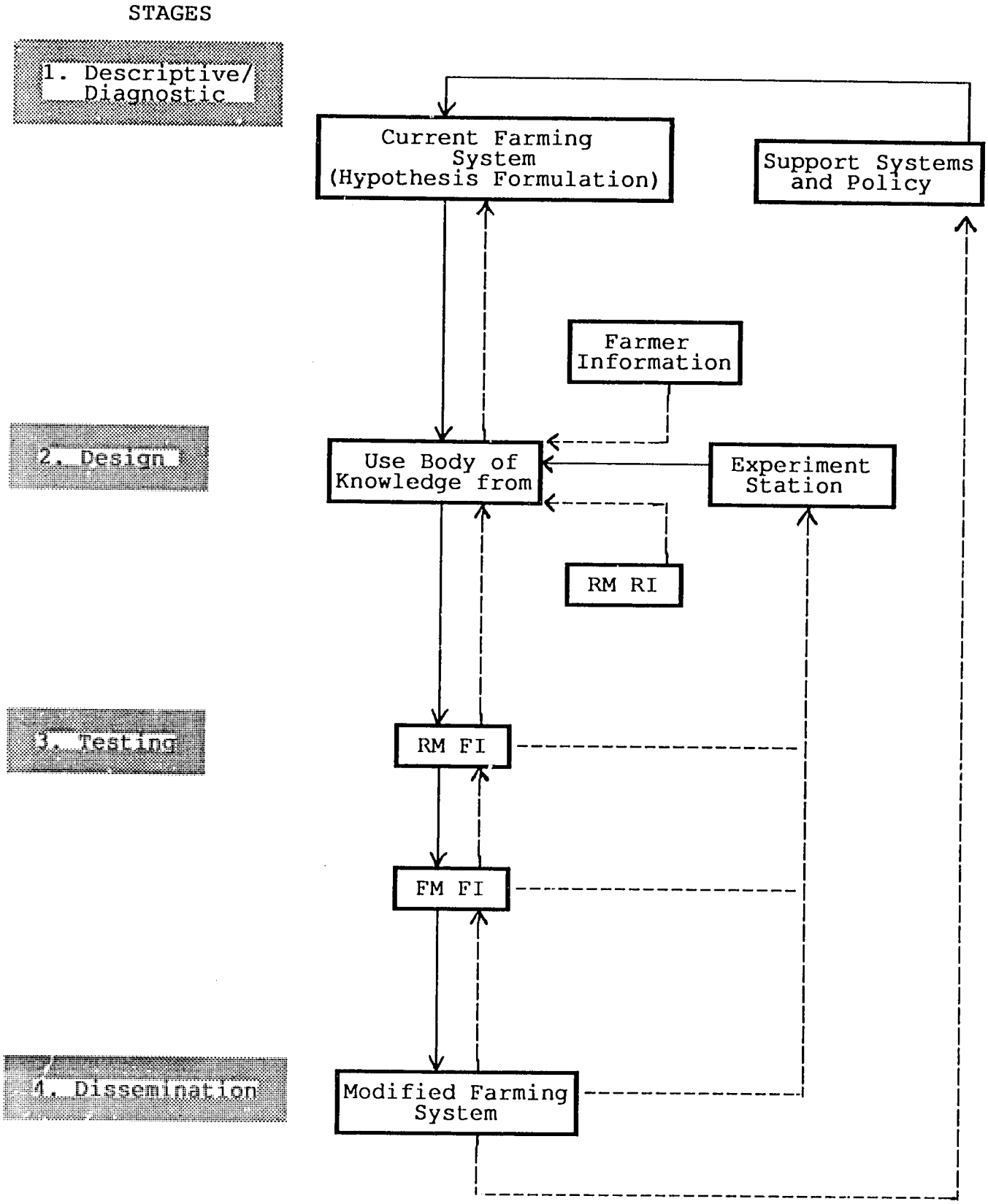
(a). ***The Descriptive or Diagnostic Stage*** in which the actual farming system is examined in the context of the "total" environment -- to identify constraints farmers face, and to determine the potential flexibility in the farming system in terms of timing, unused resources, etc. An effort is also made to understand the goals and motivation of farmers that may affect their efforts to improve the farming system.

(b). ***The Design Stage*** in which a range of strategies are identified that are thought to be relevant in dealing with the constraints determined in the descriptive or diagnostic stage. Information for designing such strategies comes from experiment station work, researcher managed and researcher implemented (RMRI) type work on farmers' fields, and from other farmers.

This stage, in essence, involves **ex ante** evaluation from the viewpoint of:

[2]. Andrew and Hildebrand [1982], Byerlee, Collinson, Perrin, Winkelmann, Biggs, Moscardi, Martinez, Harrington and Benjamin [1980], Byerlee, Harrington and Winkelmann [1981], CIMMYT [1988A and B], Dillon, Plucknett and Vallaeys [1978], Gilbert, Norman and Winch [1980], Harrington [1980], Harwood [1979], Moreno and Sanders [1978], Norman, Simmons and Hays [1982], Shaner et al., [1982], and Zandstra, Price, Litsinger and Morris [1981].

FIGURE 1.3: FARMING SYSTEMS WORK



KEY:

R	=	Researcher (Technician)
F	=	Farmer
M	=	Managed
I	=	Implemented

i. Technical feasibility -- whether the physical transferability of technical relationships established elsewhere is valid, and thereby contributes to the solution.

ii. Economic viability -- whether the proposed solution is economically viable in the local situation of the farming family.

iii. Social acceptability -- whether the proposed solution is likely to be acceptable to the farming family.

(c). ***The Testing Stage*** in which a few promising strategies, arising from the design stage, are examined and evaluated under farm conditions to determine their suitability for producing desirable and acceptable changes in the existing farming system. This stage usually consists of two steps:

i. Researcher managed but farmer implemented tests (RMFI) to establish whether transferred technical relationships are altered by farmers' management of non-treatment variables.

ii. Farmer managed and implemented (FMFI) type tests when the team are confident that relationships will hold, but need to evaluate the proposed technologies under local socio-economic circumstances.

Where transferred technical relationships appear likely to be distorted by differences in local natural conditions, researcher managed and implemented (RMRI) experiments will be necessary on farmers' fields rather than the experiment station where such trials are usually carried out. These are done before undertaking RMFI and FMFI trials which involve farmers, and therefore are always undertaken on farmers' fields. All these types of trials may be undertaken by the FS team.

(d). ***The Dissemination Stage*** in which the strategies that were identified and screened during the design and testing stage are extended to farmers.

In fact, there are no clear boundaries between the various stages. Design activity, for example, may begin before the descriptive and diagnostic stages and may continue into the testing stage, as promising alternatives emerge from researcher managed and farmer implemented type trials -- where farmers and researchers interact directly. Similarly, testing by farmers may mark the beginning of dissemination activities.

Also, it may not always be necessary to go through all stages. FS team confidence in transferability during the design/planning stage can sometimes mean going straight to FMFI work or even to the recommendation/dissemination stage. Thus, the process of FSR is recognized as being dynamic and iterative with linkages in both directions between farmers, researchers and extension staff. The iterative characteristic can improve the efficiency of the research process by providing a means of identifying and tuning improved technologies for a specific location -- that is, climatic situation, soil type and/or farmer resource base.

1.1.4 SOME CHARACTERISTICS OF FARMING SYSTEMS RESEARCH

Some of the major characteristics of farming systems research are as follows:

(a). ***Farmer Center Stage.*** The farming systems research approach involves putting the farmer, as the consumer of the improved technologies, in the center of the stage.

This approach provides an opportunity for researchers to learn from the farmer, enable him or her to have an input into the research process, and ensures that criteria relevant to him or her are used in evaluating proposed technologies. For the farming family, evaluation criteria (for the adoption of the improved technologies) can be divided into the following groups, although it should be emphasized they are not mutually exclusive [Norman, Simmons and Hays, 1982]:

i. Necessary conditions determine whether the farming family **would be able** to adopt the improved practices. Such conditions include technical feasibility, social acceptability, and compatibility with external institutions -- that is, support systems.

ii. Sufficient conditions determine whether the farmer **would be willing** to adopt the improved practices. Obviously, the necessary conditions will be influential in determining this willingness. Sufficient conditions will include the compatibility of the improved practices with the goal(s) (e.g., food self-sufficiency, profit maximization, risk minimization, etc.) of the farming family, the resources they have access to, and the farming system they now practice.

(b). ***Work With Representative Farmers.*** Although the input of farmers is critically important in farming systems research, it is impossible for FSR teams to work with all farmers. Therefore, a few are selected that are thought to be representative of all farmers. Since there are many types of farmers -- because of differences in the products they produce and the resources they possess -- it is necessary to put farmers with similar characteristics in the same group (stratification)[3]. A small sample of farmers in each of these groups is then selected to work with the farming systems research team. If the grouping and selection of farmers is carried out correctly, then the results obtained by these representative farmers should be achievable by other farmers with similar characteristics, when the technologies are extended to other farmers by extension staff.

(c). ***Involves An Interdisciplinary Approach.*** As indicated earlier (Section 1.1.2), farmers have complex farming systems. As a result, changes in one part of the farming system may have a good or bad impact on another part of the farming system. For example, as the farming systems team in Southern Region (FSSR, formerly IFPP), have always emphasized, it is not realistic, or indeed desirable, to try and increase crop productivity without considering livestock at all. This opens up the possibility for complementary and supplementary relationships in the farming system to be exploited. Also attaining a successful solution to a technical problem that has been identified, will depend on whether the farming family has the labor and money to adopt -- which is an economic issue -- and whether there are sociological reasons which would prevent them from adopting. Farming systems teams, therefore, generally consist of representatives of a number of disciplines -- usually agronomists, animal scientists, agricultural economists and sometimes sociologists. As a result, an interdisciplinary approach -- that is, a number of disciplines working together on the same problem -- has to be used to solve the problems of farmers.

(d). ***Is A Dynamic And Iterative Approach.*** Because of the dynamic nature of agriculture, research is a never-ending process since farmers always face problems, to

[3]. This discussion is developed further later (see Section 2.3) where the different strata are called recommendation domains.

a varying degree, in their farming operation -- many of which can be solved through research. Sometimes the solutions suggested as a result of research don't work, and need to be modified somewhat. This is implied in Figure 1.3, where the dotted lines indicate that such failures require moving back to an earlier stage in the farming systems research process, and repeating one or more of the steps in the research process. This makes farming systems research an iterative as well as a dynamic approach.

(e). ***Complementary To Experiment Station-Based Research.*** In the context of technology choice and development, the role of FSR is seen to be complementary to technical component research (TCR), most of which is undertaken on experiment stations [Norman and Collinson, 1986]. FSR has three such roles:

i. To look at recognized farming systems and the stock of materials and techniques accumulated from TCR, so as to be able to choose technical solutions to problems that have been identified. On-farm experimentation then adapts chosen solutions to the local situation. This is a mobilizing and adaptive role, shaping the product for an identified market.

ii. To pass back unsolved technical problems, important to the system, and therefore farmer development, to the appropriate TCR team on the experiment station. This is a role in identifying and helping to prioritize the agenda for technical research.

iii. To link with farmer clients and extension staff in local farm situations, drawing both farmers and extension workers into the technology generation process.

Similar linkages, although rarely accomplished to date, could be established with planning and development agencies concerning proposed policy/support program changes. In Botswana, these are not yet strongly developed.

1.2 RATIONALE FOR FARMING SYSTEMS RESEARCH

1.2.1 COMPARING EXPERIMENT STATION-BASED RESEARCH AND FSR

The literature frequently compares and contrasts station-based research and FSR. The tone in the discussion often implies that they are substitutes for each other. However, as has just been argued, both experiment station research and farming systems research are needed. This is because they do different things and therefore are complementary to each other.

One major difference between them is the following:

(a). On the experiment station, predominately ***applied*** research is undertaken where new technologies are created.[4]

[4]. On the experiment station, ***basic*** and ***strategic*** research are also sometimes undertaken. Basic research is designed to generate a new understanding of biological processes, while strategic research aims to solve specific research problems; for example, finding out why striga grows on sorghum but not on sunflower. However, in a research system like Botswana, neither basic nor strategic research are frequently undertaken because such types of research require highly sophisticated equipment and techniques,

(b). FSR, however, concentrates mainly on ***adaptive*** research which involves helping to adjust technologies to specific environmental conditions. FSR also helps feedback information about future priorities for applied research, to experiment stations.

To help clarify matters, Table 1.2 illustrates some of the major differences between experiment station-based research and FSR. This table, which does not detail all the differences, hopefully shows why both types of research are important and, therefore, why both are necessary.

TABLE 1.2: SOME DIFFERENCES BETWEEN EXPERIMENT STATION-BASED RESEARCH AND FSR

CHARACTERISTIC		STATION-BASED RESEARCH	FSR
Location of Trial		Usually Experiment Station	Usually On-Farm
Disciplines Involved		Often Single	Usually Several
		Mostly Technical	Technical and Social
Priority Setting for Trial:	Researcher	More Involved	Less Involved
	Farmer	Less Involved	More Involved
Experimental Design:	Complexity	Usually More	Usually Less
	Management	Researcher	Researcher or Farmer
	Implementation	Researcher	Researcher or Farmer
Degree of Experimental Control		More	Usually Less
Evaluation of Trial Results -- Factors Taken Into Account:			
Systems Perspective		Less Likely	More Likely
Technical Feasibility		Yes	Yes
Economic Viability/Reliability		Less Likely	More Likely
Social Acceptability		Less Likely	More Likely
Farmer Opinion		Not Likely	More Likely
Expense of Experimental Program:			
Fixed (Overhead) Costs		Likely to be Higher	Likely to be Lower
Variable (Recurrent) Costs		Likely to be Lower	Likely to be Higher

It is obvious that the more conventional station-based research has been somewhat successful. Such research gave rise to the Green Revolution, which enabled many farmers in Asia, in particular, to benefit from growing new high yielding varieties of wheat and rice with fertilizer, under conditions where plenty of water was available. However, it appears that many farmers with very limited resources both in Asia, and more particularly in Africa, have not benefitted from these types of technologies. This is because the environment in which they are working is much less equable, and therefore finding ways to help them, without a better understanding of both their technical and human environment, proved too difficult. Consequently, in the 1960s, FSW emerged in the low income countries to try and bring researchers on-station closer to farmers, extension/development agencies and planners. In effect, there was an increasing realization that in these areas and with limited resource farmers, there was unlikely to be an agricultural revolution. Rather, it seemed more likely that changes in the farming systems would be less spectacular, requiring more adaptive type research than was necessary in the case of the Green Revolution.

1.2.2 ADVANTAGES OF THE FSR APPROACH

Briefly, FSR does the following:

need specialist researchers, and do not need to be located in specific agro-climatic environments [Farrington and Martin, 1988].

(a). Provides a systematic way of trying to understand both the technical and human environment of farmers. In doing so it provides a method of highlighting the critical issues facing farmers[5].

(b). As a result of identifying these issues, it provides a way in which relevant research priorities can be fed back to the experiment station. Additionally, it enables research personnel, working on farmers' fields, to select appropriate technologies to address the problems that have been identified.

(c). FSR provides a way for evaluating technologies, in a practical manner, within a systems context, using criteria that are relevant to the farmer.

1.2.3 CHALLENGES FACING FSR

There are a number of challenges facing FSR that need to be understood and, where possible, addressed. Some of these are as follows:

(a). FSR is relatively new. Therefore the methodology is still evolving. This is one of the reasons this handbook has been written.

(b). Related to the methodology issue is that we need to further develop time and cost (money and people) efficient methods for undertaking FSR. This is important because of the limited resources available for undertaking research -- both on-station and on-farm.

(c). In FSR, we tend to try and help the farmer with the problems he or she has identified. Of course, the reason for this is we want to introduce an intervention that they are interested in. However, it is possible that while helping to solve the farmers' problems, we create other ones for the society, as a whole. For example, in Botswana, there exists a tradition of farmers sharing draft power. If we develop a technology that requires more draft, rather than less, it may mean that the family household controlling the draft may not be able to allow other households to also use their draft animals under a sharing arrangement. Thus, helping one individual household may harm other households in the community. Another example would be with reference to the effect of a proposed technology on maintaining the long-run productivity of the land. It is important when designing a technology to help farmers increase their productivity, that consideration is given to the possible long-term effects (e.g., decreasing the amount of productive land available) of that intervention.

(d). Establishing credibility for FSR is a major challenge, but is necessary so as to ensure that some of the limited research resources will always be allocated to it. As we have argued earlier, FSR is only one of the actors in the agricultural development process. Additionally, in a way, FSR helps facilitate a process and does not produce a product by itself. Consequently, FSR cannot claim sole credit for any technologies developed or any technologies adopted by farmers. However, it achieves credibility through its linkages and cooperative efforts with other actors in the agricultural development process. Therefore, it is important for these other actors to understand and acknowledge the contribution that FSR can make.

[5]. Although the discussion here is in terms of technologies, a similar relationship can potentially exist with planners with respect to support systems.

1.3 EXPERIENCE WITH FS WORK IN BOTSWANA

1.3.1 AGRICULTURAL RESEARCH IN BOTSWANA

Agricultural research, supported by government funds, started in Botswana in 1936 at the Morale Pasture Research Station near Mahalapye. The initial work focussed on animal production and rangeland areas, but in 1945 crop and crop strategy research work was introduced and located at Mahalapye. The headquarters for agricultural research work then moved to its current location at Sebele in 1969.

Over the years, agricultural research has been devoted to a large number of topics including the following [Addy, Farrington, Gollifer, Hunter, Stewart-Jones & Sweet, 1987][6]:

(a). ***Animal Production And Rangeland Research.*** Areas worked in have included: beef cattle breed evaluation, beef production potential under communal/cattle post and commercial ranching systems, nutritional studies of livestock, dairy production including small-scale peri-urban milk production, smallstock production including a recently instituted goat breeding program using the indigenous goat, evaluation of different livestock systems under communal grazing situations and the effect of the Tribal Land Grazing Land Program (TGLP), the nutritional limitations of natural pasture, range assessment and monitoring, stocking rate studies in the major ecological zones of the country, grazing system studies, communal grazing cell studies, control of bush and value of browse in livestock diets, range improvement and use of crop residues, control of poisonous plants, and range degradation/restoration studies.

(b). ***Arable Research.*** Initially, emphasis was placed on the identification of maize and sorghum varieties suitable for Botswana. However, later work on maize was cut back in favor of work on millet, legumes, cotton and the use of fertilizer. Even more recently, increasing attention has been devoted to the factors governing dryland farming, particularly crop husbandry and physiology, soil tillage and physics. The idea behind this research was to obtain a better understanding of Botswana's technical environment before trying to extend improved dryland farming techniques to the farming community. This paved the way to emphasizing machinery development, and the introduction of the FS approach. Current activities in crop research include: work on soil and water relationships, tillage systems, selection, breeding and agronomic work on cereal (mainly sorghum and millet) and legume (mainly cowpeas and groundnuts) crops, variety selection and plant population studies in oilseed (mainly sunflower) crops, cropping system studies including rotations and intercropping, crop protection, and irrigation particularly with reference to horticultural research.

1.3.2 EVOLUTION OF FSR WORK

It is perhaps not surprising that in the early 1970s, in the light of all the research that had been done, it was felt that it should be possible to significantly increase agricultural

[6]. Detailed discussions of the research program of the Department of Agricultural Research (DAR) can be found in the various annual reports of the Arable Research and Animal Production and Range Research (APRU) Divisions, and reports produced by the various projects that have been associated with the department.

production in the country, if the technologies were adopted by a large enough number of farmers [Addy et al., 1987]. It was apparent that agricultural production was not increasing as a result of the agricultural research program. It seemed that either the technology was not reaching the farmers or else it was unacceptable to them. Also there was concern about the failure to explain the large yield gap that often existed between the research plots and farmers' fields when the same technology was being used.

Therefore, it was decided that the way to address these issues was to initiate testing on farmers' fields. As a result of this, two projects came into existence in the mid-1970s -- namely EFSAIP (the Evaluation of Farming Systems and Agricultural Implements Project) and IFPP (the Integrated Farming Pilot Project).[7] As a result of their early technology testing work at the farm level, they found that some of the research recommendations (e.g., autumn cultivation, row planting, use of fertilizer and improved seed, good weed and pest control, crop rotation, minimum tillage and soil/water conservation) combined to form a package, based on a multi-purpose toolbar, had some limitations. However, due to the feedback process there were improvements in individual component technologies.

There was, during the next few years, an expansion in the development of what increasingly became farming systems research, with the initiation of the Agricultural Development for Ngamiland Project (ADNP)[8] in 1979, the Agricultural Technology Improvement Project (ATIP) in 1982, and the Molapo Development Project (MDP) in 1983.

Over time, all these projects increasingly embraced the FS approach, even though some did not start out as FS projects. As a result, they all now design -- with the help of technologies developed by on-farm research -- solutions to problems that have been identified with the help of farmers. Those potential solutions are then tested together with farmers on their fields.

In general, apart from IFPP (FSSR) and to a lesser extent ATIP, most of the projects have concentrated on crops rather than livestock activities. A good deal of emphasis has been placed on tillage/planting practices, followed by agronomic practices, implement testing, and the testing of individual component technologies (e.g., varieties, seed dressing, etc). Where livestock work has been undertaken in the context of FS teams, it has tended to concentrate on the crop/livestock interface (harness/yoke equipment, feed -- both specially grown and crop residues), winter fattening of cattle and small ruminants.[9]

In the early days, much of the support for FS activities in Botswana was provided from various donor agencies (i.e., British, Swedish, American and German). However, in recent years the proportion of the funding met by the Government of Botswana (GOB), has been steadily increased. Currently in 1990, FS teams are operating in the Kanye, Mahalapye, Francistown and Maun areas[10].

7. The name IFPP was later changed to Farming Systems Southern Region (FSSR).

8. This was later known as the Agricultural Ngamiland Development Project (ANDP).

9. For details on the research programs of the individual projects, see the annual reports of the Crop and Livestock (APRU) Divisions in DAR, and the annual reports and other papers produced by IFPP (FSSR), EFSAIP, ADNP (ANDP), ATIP and MDP.

10. An informative review of FSR work in Botswana is given by Frankenberger and Mitawa [1988].

1.3.3 PLANS FOR THE FUTURE THAT ARE CURRENTLY UNDERWAY

Recently, the commitment by the Government of Botswana (GOB) to FS-type work has increased not only in terms of funding, but also in terms of its institutionalization. Until now, FSSR and MDP have been located in the Department of Agricultural Field Services (DAFS)[11], and ANDP and ATIP have been in the Department of Agricultural Research (DAR). A decision has been made by GOB to locate all the teams in DAR. In addition, it is likely that DAR will appoint a national coordinator for FS work. These decisions are not only important in ensuring the continuation of FS-type work, but should help in improving the coordination and collaboration between the FS teams[12], and also between on-farm and on-station research work.

With respect to the latter point, this should be further facilitated by other decisions that have recently been made. There is a move to improve the planning, management and evaluation of research as a whole.[13] The approach, that is developing. involves the following:

(a). A number of interdisciplinary research groups, program research teams -- based on specific commodities or themes are being formed[14] -- which include representatives of both on-station and on-farm research, and possibly extension. These groups plan, manage and monitor the trials that are approved for their group.[15]

(b). At the annual Crops Division meetings -- attended by representatives of research, extension and possibly other agencies in MOA -- the research groups report results of the work undertaken during the last year, and seek formal approval for the proposed work program to be carried out during the coming year.

(c). Proposals on recommended new technologies are presented, with supporting evidence, from the research groups to the recently revitalized Recommendations Committee. This committee includes research and extension personnel, and is chaired by the Director of DAR. If approval is granted, the technology becomes officially accepted for extension and an Agrifact -- a recommendation leaflet -- is created or modified.

[11]. Recently this department has been split into two: the Department of Crop Production and Forestry, and the Department of Animal Production and Health.

[12]. Until now there have been no formal links encouraging this, although, for a number of years, personnel on the various teams have informally met twice a year; once in a meeting at which FSR issues were discussed, and the other being an on-farm workshop hosted by one of the FSR teams.

[13]. Currently the plan applies only to the Arable Research Division in DAR, not the Animal Production and Range Research Division.

[14]. Among those currently proposed are: cereals, legumes, horticulture, vertisols, soil and water management, and possibly farming systems research.

[15]. There has in fact, been one group, a National Tillage Team, that has been meeting successfully on a regular basis for over a year. This team, consisting of research and extension/development agency staff, has been collaborating on a multi-locational trial, at nine different sites -- eight of which are on farmers' fields -- throughout the country. The main objective of the trial is to systematically compare different tillage treatments designed to improve water availability to the plants.

This is then published by the Department of Agricultural Field Services (DAFS), and distributed to extension staff (i.e., Agricultural Demonstrators) for dissemination to farmers.

Also, to further aid in collaboration between on-station and on-farm research work, there is currently a proposal to have a series of sub-stations established, where staff members will be responsible for on-station and on-farm work. Thus, the recent decision to institutionalize FSR in Botswana is resulting in strategies to encourage greater integration and coordination of FS work.

Of course, linkages with farmers, extension staff and even planners, are critically important if FS teams are to fulfill their potential. The links between FSR and farmers and extension staff will be discussed in other sections in the handbook, as will details on the on-farm and on-station research linkage.

1.4 ORGANIZATION OF THE HANDBOOK

1.4.1 PURPOSE OF THE HANDBOOK

This handbook is not designed to be a comprehensive manual for undertaking farming systems work. A number of such manuals already exist, and multiple copies of some of these have been deposited in the DAR library. A list of these is given in Section 1.4.3 and are available on loan from the library on a long-term basis. Throughout this handbook we have made frequent reference to these manuals thereby directing the reader to more detailed discussions of the topics under consideration.

Instead, in this handbook, an effort is made to discuss some of the major issues that we have had to address while undertaking farm systems research in the harsh climatic environment of Botswana. We have also discussed how we have resolved these issues, making liberal use of examples from Botswana. The handbook has therefore been designed primarily for FSR practitioners in Botswana, although over the years we have developed some innovative techniques that could be of interest to those outside Botswana who are involved in FSR.

Because the purpose of the handbook is to provide some practical guidelines for practitioners to undertake FSR in Botswana, there is relatively little emphasis on theoretical materials. Also, since it builds on experiences in Botswana, and is not designed to be a comprehensive handbook, some topics have not been discussed in detail. Finally, because FSR methodology is still undergoing some evolution, various parts of the handbook may need to be updated in the future.

Although the handbook has been written by ATIP personnel, members of other FSR teams in Botswana have had an opportunity to review it. Hopefully, as a result, the handbook represents the collective view of how FSR work is currently undertaken in Botswana.

1.4.2 LAYOUT OF THE HANDBOOK

In the remaining chapters of Part I, Chapter 2 deals with some general issues concerning FSR, while Chapter 3 concentrates on linkages between farming systems teams and the various actors in the agricultural development process. Part II considers general guidelines for implementing FSR, with Chapter 4 dealing with description and diagnosis, and Chapter 5 with the design and testing stages of FSR. Specific implementation procedures are

emphasized in Part III, with chapters on general management issues (Chapter 6), surveys (Chapter 7), crop production trials (Chapter 8), and livestock trials (Chapter 9). Part IV deals with analytical procedures with chapters on data management (Chapter 10), data analysis (Chapter 11) and reporting results (Chapter 12). The final part has only one chapter concentrating on guidelines concerning special farmer linkage activities.

To help the readers of this handbook, there are three additional features. These are as follows:

(a). At the end of each chapter a list of useful readings is given which deal with the topics discussed in the chapter. Where relevant, specific page numbers have been cited. This list is not meant to indicate all of the possible references available, nor does it mean that these are the best. However, they are useful references and many of the publications are available in the DAR library. A complete reference list is also presented at the end of the handbook (Appendix A).

(b). Because there are many technical terms used in the handbook, a glossary defining these terms is provided (Appendix B). Generally, the first time a technical term is used in the text, it is also defined at that point.

(c). A large number of acronyms are used in the handbook. A list defining these is provided (Appendix C).

(d). Many different data collection and survey forms have been used by ATIP staff over the years. Since these can serve as useful examples of both how to, and on occasion how not to(!), collect data, many of them have been reproduced and put in folders. None of them are perfect, but they are potentially useful in providing ideas to FS practitioners in Botswana on how to design forms in the future. Because of the expense in processing the forms to make them suitable for printing, they are available in their original form as an annex to this handbook and can be checked out of the DAR library [Worman, Norman and Ware-Snyder 1990]. A list of the forms in the annex is given in Appendix D of this handbook.

1.4.3 MAJOR REFERENCES AVAILABLE IN THE DAR LIBRARY

Multiple copies of some the major references on how to do FSR work are available for long-term loan from the Department of Agricultural Research (DAR) library. These include the following:

Amir, P., and H. Knipscheer, 1989. ***Conducting On-farm Animal Research: Procedures and Economic Analysis.*** Morrilton, Arkansas, USA and Ottawa, Canada: Winrock International and International Development Research Center.

Andrew, C.O., and P.E. Hildebrand, 1982. ***Planning and Conducting Applied Agricultural Research.*** Boulder, Colorado, USA: Westview Press.

Caldwell, J., and L. Walecka (eds.), 1987. "Design Techniques for On-Farm Experimentation". ***FSR/E Training Units: Volume II.*** Second Edition. Gainesville, Florida, USA: University of Florida, 1987.

Caldwell, J., D. Taylor, and L. Walecka (eds.), 1987. "Analysis and Interpretation of On-Farm Experimentation". ***FSR/E Training Units: Volume III.*** Gainesville, Florida, USA: University of Florida.

Caldwell, J., T. Frankenberger, T., D. Taylor, and L. Walecka (eds.), 1987. "Diagnosis Design and Analysis in Farming Systems Research and Extension". ***FSR/E Training Units: Volume I, II and III Trainer's Manual.*** Gainesville, Florida, USA: University of Florida.

Chambers, R., A. Pacey, and L.A. Thrupp (Eds.), 1989. ***Farmer First: Farmer Innovation and Agricultural Research.*** Exeter, UK: Intermediate Technology Publications.

CIMMYT, 1988A. ***From Agronomic Data to Farmer Recommendations: An Economics Training Manual.*** Completely Revised Edition. Londres, Mexico: CIMMYT.

Frankenberger, T., and L. Walecka (eds.), 1987. "Diagnosis in Farming Systems Research and Extension". ***FSR/E Training Units: Volume I.*** Second Edition. Gainesville, Florida, USA: University of Florida.

Gomez, K.A., and A.A. Gomez, 1984. ***Statistical Procedures for Agricultural Research.*** Second Edition. Los Banos, Philippines: International Rice Research Institute, John Wiley and Sons.

Hildebrand, P., and F. Poey, 1985. ***On-Farm Agronomic Trials in Farming Systems Research and Extension.*** Boulder, Colorado, USA: Lynne Rienner.

Shaner, W.W., P.F. Philipp, and W.R. Schmehl, 1982. ***Farming Systems Research and Development: Guidelines for Developing Countries.*** Boulder, Colorado, USA: Westview Press.

Zandstra, H., E. Price, J. Litsinger, and R. Morris, 1981. ***A Methodology for On-Farm Cropping Systems Research.*** Los Banos, Philippines: International Rice Research Institute.

1.5 USEFUL REFERENCES

Section 1.1:

Dillon, Plucknett and Vallaeys, 1978.
Gilbert, Norman and Winch, 1980: pp. 6-20.
Norman and Collinson, 1986.
Norman, Simmons and Hays, 1982: pp. 16-28.
Shaner, Philipp, and Schmehl, 1982: pp. 13-20.
Zandstra, Price, Litsinger and Morris, 1981: pp. 3-8.

Section 1.2:

Farrington, J., and A. Martin, 1988: pp. 15-22.
Norman, D., 1989A.

Section 1.3:

Addy, Farrington, Gollifer, Hunter, Stewart-Jones and Sweet, 1987.
Frankenberger, T., and G. Mitawa, 1988.

CHAPTER 2: GENERAL ISSUES IN FARMING SYSTEMS WORK

2.1 DISTINCT TYPES OF FARMING SYSTEMS WORK

2.1.1 THREE APPROACHES

Earlier (Section 1.1.3) it was indicated that there are a number of ways to undertake FSR. A distinctive feature of FSR is that a systems perspective is constantly borne in mind. Within this framework, one can either look at a small or large number of variables in the system. In general, because of the complexities of simultaneously handling a large number of variables, most FS programs have tended to limit the number of variables they study, and regard the other factors that influence the farming system as parameters or constants.

Three general approaches to FSR have been defined which relate to the number of variables being investigated. These approaches can be as FSR "in the large", "in the small" and "with a pre-determined focus" [Norman and Collinson, 1986][1].

FSR "in the large" treats all system parameters as potentially variable in a wide ranging search for improvement. It is similar to the development of a completely new farming system. It implies revolutionary rather than evolutionary changes in the farming system. It is not particularly complex in concept, but is extremely difficult to implement. Therefore FSR "in the large" is rarely undertaken and does not exist in FS work in Botswana.[2]

In contrast, both FSR "in the small" and FSR "with a pre-determined focus" recognize that small-scale farmers evolve from their existing situation in steps. The content and scale of these steps must be compatible with farmer resource endowments, the level of risk they are willing to undertake, and their management capabilities. FS researchers work within the system, and it involves identifying potential development steps. Because both these approaches to FS work recognize the step-by-step development process in small-scale farming, and both seek to identify steps in technology, there has been confusion between the two. The difference is that FS "in the small" arrives at a focus within the system in the course of diagnosis, while FS "with a pre-determined focus" moves into the system to research an enterprise, or one facet of an enterprise, looking for improvements within that focus which are compatible with the whole farming system.

Both FSR "with a pre-determined focus" and FSR "in the small" are currently used in Botswana. A couple of examples are as follows:

(a). Often commodity researchers on the experiment station want FS workers to evaluate specific technologies they have developed to see how they fit in with the farming systems currently used by farmers. This is FSR "with a pre-determined focus". Examples would be testing cowpea varieties, evaluating the desirability of hilling

[1]. Dillon and Anderson [1984] have assigned different names to these approaches, namely replacement, revision and adjustment, respectively.

[2]. However, some of the work carried out by experiment station-based researchers with a systems perspective could be considered a type of FSR "in the large". An example, in the Botswana context, would be watershed management work that has been undertaken during the last few years.

groundnuts, ascertaining whether the Dutch hoe can help the weeding operation, etc.

(b). In our FS work we have found the major problem of farmers tends to revolve around the plowing-planting bottleneck or constraint. Availability of water for plant growth is the basic problem, while limited planting days and draft availability impose additional constraints on the extent to which the limited water can be used. Since this was diagnosed as a major problem early in our work, we have spent a great deal of effort in trying to find solutions to this constraint. This is an example of FSR "in the small"[3].

2.1.2 THE SITUATION IN BOTSWANA

The current and proposed organization of the agricultural research process in Botswana provides opportunities for FSR "with a pre-determined focus", and FSR "in the small" to operate in Botswana. The Program Research Teams can assist with the former, while the proposal to have FS teams operating out of regional sub-stations will also enable the latter approach to be used.

The combination of approaches is highly desirable. There are obvious advantages of FSR "with a pre-determined focus" for commodity researchers on experiment stations, but there are also distinct limitations including:[4]

(a). The range of problems identified in the system is pre-determined. Research efforts may be focussed on problems and solutions which may not be attractive to farmers whose primary concerns may be elsewhere in the system.

(b). It cannot offer a means for identifying and ranking technical research problems requiring research resource allocation across commodities; a major potential contribution of a full farming systems perspective.

(c). FSR's important linkage role with extension is more difficult to achieve if the focus is excessively limited. Its orientation as well as organization is less compatible with successful extension.

In contrast, the advantages of FSR "in the small" are in a sense opposite of the limitations stated for FSR "with a pre-determined focus", namely:

(a). It gives priority to the problems of farmers.
(b). Because it has a wider focus, it can better assist in prioritizing research goals on the research station.
(c). Its area orientation and organization is wholly compatible with extension.

2.1.3 LEVERAGE AND BREAKING CONSTRAINTS

The two approaches of FSR discussed in the preceding section have different implications

[3]. See also discussion on leverage and non-leverage interventions in Section 2.1.3.

[4]. For a more complete discussion on the limitations and advantages of both FSR "with a pre-determined focus", and FSR "in the small", see Norman and Collinson [1986: pp. 25-28].

for the degree of leverage obtained in the system, and the problem of breaking constraints versus exploiting flexibility in the system. These topics are now examined in a little more detail.

2.1.3.1 Leverage

FSR workers are obviously interested in maximizing improvement in the productivity of the farming systems being implemented by farmers. In order to accomplish this, it is important to identify the parts of the farming system where adoption of a change can have the greatest positive impact on productivity. In such a situation, potential leverage on the farming system is maximized.

Although we do not view FSR "in the large" as being a viable option, there is, however, still the difficult issue of variables to parameters. Is it wise, for example, to focus research on a pre-determined commodity (i.e., FSR "with a pre-determined focus") rather than on the whole farming system, or on the crop subsystem (i.e., FSR "in the small")?

When research is undertaken where the pre-determined enterprise in question is a major absorber of farm resources, then that enterprise will usually offer the best leverage on such system-problems as deficient income, excessive risk and seasonal variability in the use of farmer-owned resources. In fact, this small variable to parameter ratio approach is methodologically much easier to undertake than one in which the ratio of variables to parameters is much larger. Geographically-based FS teams have the responsibility for looking at all crop and livestock enterprises in the system. Obviously, most leverage can be obtained with the major crop or livestock enterprises. However, this still is a complex situation when viewing the relationships between the various enterprises. Certainly focusing on the broader farming system is advisable when there appears to be little scope for improvement in the farmer's major enterprise.

2.1.3.2 Breaking Constraints Or Exploiting Flexibility

There are two possible ways of dealing with an identified constraint: break the constraint, or avoid the constraint by exploiting the flexibility in the farming system. For example, in a situation where sorghum is affected by a particular disease, numerous strategies could be applied to deal with the problem. The constraint may perhaps be broken by applying a seed dressing (requiring an input distribution system), breeding a disease resistent sorghum (a long-term strategy requiring an input distribution system), or by exploiting the flexibility in the farming system by planting the sorghum at a sub-optimal time (in terms of yield potential) which reduces or eliminates the disease attack. The decision on which approach to use in dealing with the constraint will depend on its severity, the flexibility that exists in the existing farming system, and the availability of potential improved strategies that break the constraints or exploit the flexibility. Breaking a constraint is a much more difficult problem both for researchers and farmers, than the strategy of exploiting flexibility. However, major long-term increases in productivity have to come through breaking constraints. This must be a step-by-step approach moving away from the present system towards a new one -- each step being one that is acceptable and absorbable by farmers.

2.1.3.3 The Botswana Context

In Botswana, FS teams work with what are called "non-leverage" and "leverage" interventions. For example, a good deal of the work done in collaboration with the

commodity researchers, on the experiment station, has a non-or minimal leverage characteristic -- particularly in the case of an enterprise that is not a major component in the farming system. However, adoption of the proposed changes can help improve the productivity of that enterprise, in particular, and possibly have an impact on the farming system as a whole. This occurs if the enterprise concerned uses a significant proportion of the resources used in implementing the farming system as a whole.

FS teams in Botswana are willing to support work with low-leverage characteristics because of the difficulty, in this harsh climatic environment, of developing interventions with a high leverage characteristic that will be readily adopted by farmers. Because of the difficult environmental conditions, there is little flexibility in the farming system, since a key management factor is the ability of farmers to plow and plant when it is likely to improve water availability for plant growth, and to improve the efficiency of water use. Therefore, researchers in our situation are faced with the challenge of trying to develop relevant technologies to break a major constraint, rather than having the easier task of developing technologies that will avoid the constraint, by exploiting the flexibility that exists within the farming system [Norman and Collinson, 1986]. In fact, if one looks at the success of FSR to date, it has generally been more successful in more equable climates than exist in Botswana. In examining the relative success of FSR in such environments, it is apparent that much of it can be attributed to exploitation of flexibility in the farming system -- often requiring only minor changes on the part of the farmer -- rather than breaking constraints. Technologies involving exploiting flexibility in the farming system are thus more likely to be spontaneously adopted, and are less likely to require rigorous farmer training programs to encourage their adoption.

Under the harsh climatic conditions of Botswana, major emphasis will have to be on developing technologies that break constraints. Adoption of such technologies by farmers involves major changes in their farming systems. For example, much of the ATIP work has concentrated on the plowing-planting operation. However, strategies to improve water availability to the plant at planting time, require more draft than the traditional strategy of broadcasting the seed, and plowing it in.

Therefore, in summary, a good deal of the FS work, done in Botswana, "with a pre-determined focus" tends to have a low leverage characteristic, while FS work "in the small" tends to have a high leverage characteristic, but unfortunately involves interventions that have to break the major constraint of limited water availability, rather than being able to exploit the little flexibility that generally exists in Botswana farming systems.

2.2 FIELD TEAMS AND INTERDISCIPLINARY COOPERATION

2.2.1 COMPOSITION OF THE FIELD TEAMS

In Botswana, the usual disciplines represented on the farming systems teams have been an agronomist and an agricultural economist.[5] However, there are two other disciplines that play a very important role in farming systems work in Botswana. These are animal science and rural sociology.

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[5]. In addition, of course, there are a number of support staff such as technicians, secretaries, enumerators, drivers, etc.

(a). ***Animal Science.*** Animal scientists have, to date, rarely been included in FS teams in Botswana.[6] Three possible reasons for this poor representation include:

i. The major thrust of FS work in Botswana has, to-date, been on crop activities.
ii. There has been a shortage of animal scientists to work in FS teams.
iii. As discussed elsewhere in the handbook (see Section 2.4.2), there are major methodological problems associated with successfully conducting animal science work on-farm.

However, it is generally recognized that animal science can make a very important contribution to FSR in the Botswana environment, where crop and livestock activities are very closely linked. Therefore in the future, participation by such scientists needs to be encouraged.

(b). ***Rural Sociology.*** The rural sociology input into FS work has been, and is likely to continue, to be provided by the Rural Sociology Unit in the Division of Planning and Statistics. This relationship should continue to work well since the unit has been very responsive to requests for collaborative work[7].

Although the basic disciplines involved in farming systems work, in Botswana, are those discussed above it is important to emphasize that other expertise can be tapped through linkage arrangements.

2.2.2 ENSURING INTERDISCIPLINARY COOPERATION

It is very important for FS team members to work in an interdisciplinary manner rather than a multidisciplinary manner. A multidisciplinary approach involves scientists and several disciplines, but the effort is planned, executed and evaluated by each person separately. On the other hand, the much more desirable interdisciplinary approach involves input from several disciplines with the effort being mutually planned, executed and evaluated. How can this desirable interdisciplinary approach be achieved?[8] The factors contributing to bringing this about can be divided into two major groups: pre-conditions and operational conditions. Each of these are discussed in the following sections:

2.2.3 PRE-CONDITIONS

The pre-conditions can be viewed as more attitudinal in nature. Characteristics that are very

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[6]. FSSR -- formerly IFPP -- used to have an animal scientist, but the only team which now has full-time animal science representation is ATIP Francistown. Recently the MDP has also recently employed a full time animal traction expert because of the critical importance of draft power in crop cultivation.

[7]. After three years of operation, the MDP employed a rural sociologist/agricultural economist in recognition of the potential contribution of rural sociology.

[8]. In the following discussion attention is confined to the characteristics and activities of the FSR team itself. However, it is important to note that the institutional setting and the reward systems are also important contributors to the morale of the team members, and the effectiveness of this type of work.

important in creating a favorable environment for interdisciplinary work include the following:

(a). The personalities of the team members have to be compatible.
(b). Each team member has to have confidence in the contribution that their own discipline can make to the total research process.
(c). Each team member, however, must also have a healthy respect for the role of other disciplines, and the limitations that exist with respect to their own discipline.
(d). Individual team members must be able to listen, understand and accept other viewpoints, and in the light of these, be prepared to modify their own views. A willingness to compromise rather than to be dogmatic, is important.

2.2.4 OPERATIONAL CONDITIONS

At the outset it should be emphasized that nothing constructive will happen unless the pre-conditions discussed above, are fulfilled. The strategies mentioned in this section simply help to create a more formalized structure that will assist in strengthening interdisciplinary work.

The keys to operating effectively in an interdisciplinary mode are:

(a). Ensuring good communication between the team members.
(b). Assuming joint responsibility in planning, implementation, analysis, writing-up and disseminating the results of the research program.
(c). Making sure that recognition for work done is equitably distributed.

With reference to (b) above, this does not mean that everyone should contribute equally in all individual activities, but rather, in terms of the overall effort, everyone should play their part. Obviously the roles and skills of specific disciplines and individuals should be taken into account in the apportioning process. As will be shown shortly (Section 2.4), it is apparent that the agronomist is likely to take major responsibility for RMRI work, while the agricultural economist plays a much more visible role at the FMFI stage.[9] Also, one team member may have special administrative or analytical talents that can be constructively exploited for the benefit of the team as a whole.

Strategies that we have found important in team building and encouraging interdisciplinary cooperation are as follows:

(a). It is important that regular team meetings are held to discuss both administrative and professional matters. Sometimes we have found it valuable to have outside representation, to help the team think through issues, to provide specific expertise, and to encourage the development of linkages.

(b). There should be an equitable sharing of administrative responsibilities. This is particularly relevant in cases where teams are very small and there may be little advantage to having a specific team leader.

(c). There should be careful coordination in the planning, implementation and evaluation

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[9]. Another example of the roles to be played by the different disciplines at various stages in the FSR process is given in Caldwell, Frankenberger, Taylor and Walecka [1987: p. V1.1 T-9].

of the various items in the work program. Since most items in the work program are likely to involve more than one discipline we have found that it is important:

i. That the workplan which is developed should result not only from discussions between the team members, but through interaction with the extension personnel in the region, experiment-station based researchers and, of course, farmers.

ii. Well before the agricultural cycle starts in September/October, it is important to write down for each proposed trial, survey or study in the work program, the objectives, a justification for doing the work, and the approach to be used.

iii. It is also important at this stage to designate someone who takes primary responsibility for the trial, survey or study.

iv. Additionally at this time it is important to obtain any special materials for the proposed trial, survey or study; to enlist any necessary support from farmers; to agree on the data collection procedure and forms that are to be used; and on the possible analytical framework for evaluating the results.

v. Finally, at this stage, responsibilities for different activities with reference to the specific trial, survey or study need to be apportioned. Some of these activities or responsibilities will be done jointly.[10] A protocol on the list of activities, the name of the person responsible for supervising them and the expected dates they need to be done by, is required for each trial, survey or study in the work program. Such a list is desirable to facilitate communication and to help to ensure successful implementation of the work program. This can be supplemented during the implementation stage by a checklist indicating, by farmer, for each trial, the dates the various activities were undertaken.

vi. It is important that analysis and writing up is done in a timely manner, and that joint authorship of papers is encouraged.

vii. After approval by the relevant authorities within DAR, the results of the work should be distributed in a timely manner to interested institutions and individuals.

2.2.5 INCORPORATING OUTSIDE EXPERTISE

It is obvious that FS teams themselves do not have all the expertise necessary to undertake FS work. As has been emphasized repeatedly, FSR is very dependent upon contributions by people outside the teams. There are at least three groups of people who have important roles to play in helping to plan, implement, evaluate and use the results of FS work. These are, of course, farmers, experiment station-based researchers, extension/development staff and

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[10]. Informal surveys (see Section 7.2.4) can be a good way of getting people to work together as a team. However, since the team members in Botswana FSR teams do sometimes change, this way of getting team members to initially work together may not always be possible.

planners.[11] Linkages between FS teams and these various groups of individuals are discussed in the Chapter 3, namely farmers (Section 3.1), experiment station-based researchers (Section 3.2), extension personnel (Section 3.3), and planners (Section 3.4).

Although these linkages are important, the relative contribution that each linkage will make will be dependent on the stage in the FSR process. In Figure 2.1 the relative contributions at each research stage are schematically indicated. However, it should be borne in mind that a number of research activities are likely to be occurring at the same time, some of which are likely to be at different stages in the research process. Therefore linkages are likely to be important all the time.

2.3 RECOMMENDATION DOMAINS

2.3.1 RECOMMENDATIONS

A recommendation is information that farmers can use to improve the productivity of their resources (farming system) [CIMMYT, 1988A]. A good or successful recommendation would therefore consist of the practices which farmers would follow, given their current resources, if they had all the information actually available to the researchers. Sometimes farmers will be able to use a recommendation directly; such as in the case of a particular variety. On the other hand, they may adjust it in some way to fit their own conditions and needs; as in the case of a fertilizer level or storage technique. The data upon which the recommendations are based must be relevant to the farmers' own agro-ecological (technical element) conditions, and the evaluation of those data must be consistent with the farmers' goals and socio-economic (human element) circumstances. The issue is: how can this be achieved especially when every farmer operates under slightly different circumstances, and therefore for whom slightly different technologies might be relevant?

2.3.2 RECOMMENDATION DOMAINS

Obviously the development of recommendations for farmers must be made as efficient as possible. Since it is impossible to make a separate recommendation for each farmer, we have to make a practical compromise. We do this by stratifying the farmers we are working with into homogeneous groups. Farmers in these groups should have similar circumstances and problems. In this situation it is usually assumed that the same recommendation will be suitable for all the farmers in the group. CIMMYT [Byerlee et al., 1980; CIMMYT, 1988A] refer to such a group of farmers as a recommendation domain. Recommendation domains may be defined by agro-ecological (technical) and/or by socio-economic (human) circumstances. The definition of the recommendation domain depends on the particular recommendation [CIMMYT, 1988A]. Two examples, for Botswana, are as follows:

(a). An underlying problem for all farmers is the limited availability of water for plant growth. Consequently a key management factor is their ability to perform timely operations, particularly for plowing and planting, in order to make more water available for germination and plant growth and to improve the efficiency of water use. The ability to pursue "timeliness" is, however, not a function of management alone but also of draft resources available to farmers. It is, for example, much easier for a farmer owning a tractor to carry out timely operations, than for a farmer hiring

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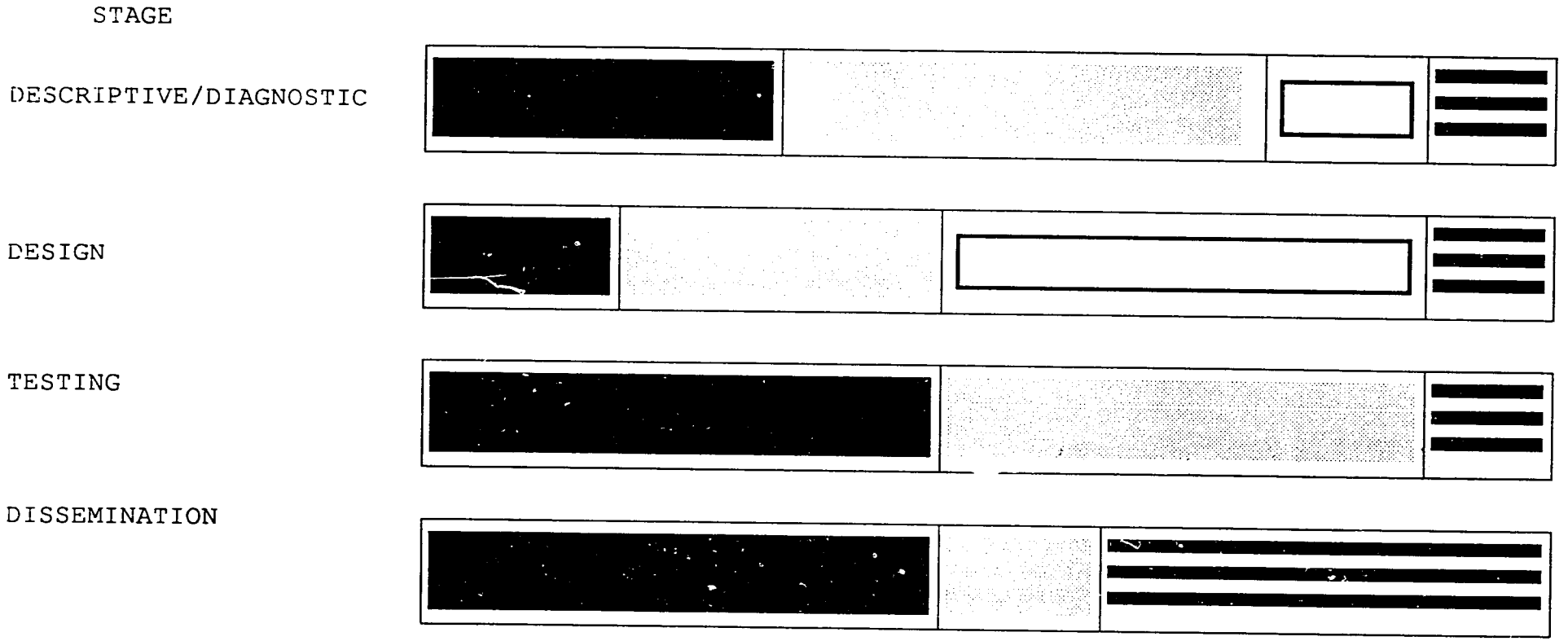
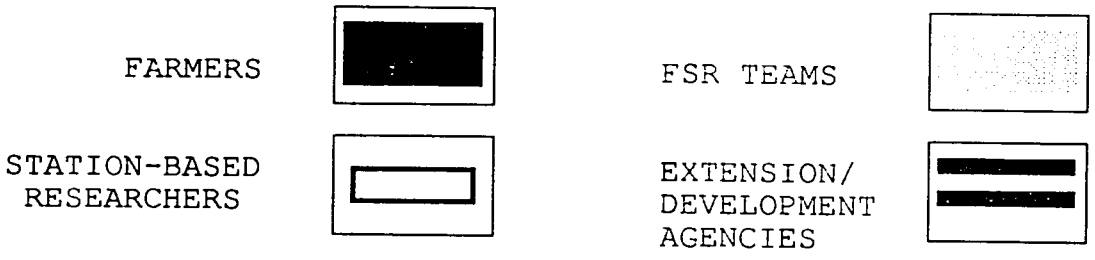
[11]. There is also another group, consultants, who are, however, usually associated with the experiment station-based research, extension or planning institutions.

FIGURE 2.1: RELATIVE CONTRIBUTIONS OF DIFFERENT "ACTORS" AT DIFFERENT STAGES IN THE FSR PROCESS[a]



LEGEND



a. The boxes reflect relative times not total time. If total time had been given, then the total size of the boxes at each stage would be

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Date: March 26, 1990

donkeys. Although the problem for both farmers is the same, the potential solutions for helping them will be different. Therefore in our work we have allocated such farmers to different recommendation domains.

(b). Over the years we have done a great deal of crop variety testing for experiment station-based researchers. One example, is the cowpea variety ER-7 which has now been officially released. In the case of this variety, there was no need to differentiate the farmers according to different socio-economic groups. Rather, the appropriate recommendation domain appears to be all farmers in a particular geographic area (i.e., eastern half of Botswana).

Therefore by dividing farmers into homogeneous groups or recommendation domains we are recognizing:

(a). The heterogeneity that exists in the farming population.
(b). The likelihood that farmers, within a group, will have similar problems.
(c). The increased probability that farmers, within a group, will be interested in the same potential solution to the identified problem(s).

Thus the purpose of the groups is to highlight similarities within the recommendation domains, and the differences between and among the recommendation domains. Similarities and differences are important only with respect to our objectives: increasing agricultural productivity by establishing experiments and generating recommendations [Frankenberger and Walecka, 1987: p. 66].

Because farm families differ from one another, we need to distinguish the characteristics on which they vary, and how those variables relate to the problems they have, and the usefulness of solutions to those problems [Frankenberger and Walecka, 1987: p. 66]. This is not always an easy exercise.

2.3.3 IMPORTANT ISSUES CONCERNING RECOMMENDATION DOMAINS

There are a number of issues with respect to recommendation domains that are important to bear in mind:

(a). ***Differentiation Between Recommendation Domains And Agro-Ecological Zones.*** There is a fundamental difference between the two. The difference is that recommendation domains are defined by farmer circumstances, practices, problems and solutions, while agro-ecological zones are differentiated by the physical and biological characteristics of the geographical areas [Frankenberger and Walecka, 1987: p. 69]. Consequently, although there may be a large number of farmers in one agro-ecological zone, it is possible for those farmers to be in a number of recommendation domains.

(b). ***Dynamic Nature Of Recommendation Domains.*** As was seen in the examples given in Section 2.3.2 above, the recommendation domain is not necessarily the same for all technology recommendations that are developed. Different recommendation domains may be desirable for different problems and related solutions.

(c). ***Iterative Characteristic In Defining Recommendation Domains.*** Recommendation domains are identified, defined, and redefined throughout the process of on-farm research. For example, they may be tentatively described during the first diagnosis. Then the information derived from planting research trials, in locations representative

of the recommendation domains, may assist in defining the domains. However, the final definition may not be developed until the recommendation is ready to be passed on to the farmers [CIMMYT, 1988A][12].

When interpreting experimental data to make our recommendations, it is important to have a fairly clear idea of the group of farmers who will be able to use this information. One must consider not only the agro-climatic range over which the results will be relevant, but also whether such factors as different management practices or access to resources will be important in causing some farmers to interpret the results differently from others.

An example from the ATIP work helps illustrate this issue. Over the years, a great deal of on-farm experimentation has been done with double plowing -- a strategy designed to encourage greater infiltration of water into the soil, thus making more water available for plant growth. In early ATIP work, we considered it a general strategy suitable for all farmers with available draft power. However, more recent experimental work combined with economic analysis, has made us re-evaluate the proposed recommendation domain. We have now concluded that double plowing gives better and more consistent results on deeper soils with higher water holding capacity. In addition, it is likely to be most suitable for farmers who control their own draft power, are faced with either a weeding labor constraint, or a land constraint.[13]

As CIMMYT [1988A: p. 58], emphasize:

> "The important point is that researchers must have a clear and consistent definition of the recommendation domain whose experiments will be submitted to economic analysis. Domain definitions are reviewed and refined during the experimental process. As the number of possible defining characteristics for domains is greater than the number of locations to be planted, careful selection of experimental locations is important. The routine collection of information adequate to describe each location (e.g., elevation, soil, cropping history, management practices) is a most important activity, without which across-location interpretation is impossible."

(d). ***Short-Cuts To A Precise Definition Of A Recommendation Domain.*** By defining a recommendation domain for a particular technology, extension staff are alerted to what farmers are likely to benefit from the technology, and therefore who should be encouraged to adopt it. Such targeting information can be helpful in facilitating the work of extension staff. However, there are two potential disadvantages with respect to this, namely:

i. The possibility of making mistakes in defining; time delays necessary in defining; and the difficulty of defining a precise recommendation domain.
ii. The possibility that farmers may use the technology in a way not envisioned by the research worker, therefore possibly changing the recommendation

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[12]. This is why sometimes in the literature the term research domain is used, and it is only called a recommendation domain after the iterative process is completed.

[13]. Another good example, is the response to nitrogen in maize described by CIMMYT [1988A: p. 57].

domain for which it is valid.

Obviously, monitoring the adoption of the technology can help in refining the definition of the recommendation domain. One short-cut in Botswana -- that is now being used to an increasing extent -- is the use of research-oriented farmer groups in testing technologies (see Section 13.1). Briefly, this involves offering a number of technologies to the farmers from which they select those they are interested in testing. This provides us with a quick indication of the possible recommendation domain for the proposed technology, and reduces the chance of possible errors in the definition. One example of avoiding such an error occurred with respect to the hand pulled rotary injection row planter. We initially thought it would be most suitable for families who did not have control of draft animals. However, when tested in a farmer group situation, some interest was expressed by families with control of draft, particularly for planting small areas, and in cases where women who found row planting with animal draft power more difficult, did the planting.

2.4 CLASSIFICATION OF TRIALS

2.4.1 TRIAL TYPES

As has been emphasized earlier (Section 1.1.1), FS workers tend to have multiple clients, who they interact with on a day-to-day basis -- namely farmers, station-based researchers, extension and development agency staff, and sometimes planners. We have found, over the years, that similar types of trials do not have equal appeal to all the clients. As a result, we make substantial use of three different types of trials. These trials can be differentiated on the basis of who manages and who implements the trial, i.e., researcher (technician) or farmer (Table 2.1).[14] Thus three major types of trials are possible:

(a). Researcher managed and researcher implemented (RMRI).
(b). Researcher managed and farmer implemented (RMFI).
(c). Farmer managed and farmer implemented (FMFI).

There is also another type of trial, called superimposed, that has considerable potential, but we have not used a great deal to date. This type of trial will be discussed separately (Section 2.4.4).

2.4.2 CHARACTERISTICS OF MAJOR TRIAL TYPES

A careful study of Table 2.1 indicates that the three trial types can be differentiated in terms of research objectives, methods, experimental design, types of data collected, methods of analysis, and evaluation criteria. Generally in FSR, technology design work begins at the RMRI level and then when a technology is thought to be appropriate is passed on for testing with the farmer, first at the RMFI level, and then at the FMFI level. Obviously the farmer becomes progressively more involved as one moves from experimentation at the RMRI to the FMFI level. Farmer groups (see Section 13.1) are particularly useful for implementing trials at the FMFI level and to some extent at the RMFI level. In RMRI type trials, undertaken on-farm, the researcher input is much greater. However, even here in what is usually design-type work, we have been able to elicit farmers' opinions by bringing a group

[14]. Another table looking at characteristics of different types of trials is given in Caldwell and Waleckа [1987: p. 270]

TABLE 2.1: EXPECTATIONS OF DIFFERENT TYPES OF TRIALS[a]

Item	Researcher Managed and Researcher Implemented (RMRI)	Researcher Managed and Farmer Implemented (RMFI)	Farmer Managed and Farmer Implemented (FMFI)
Experimental:			
Stage:	Design[b]	1st stage testing	2nd stage testing[c]
Design:			
Complexity	Most	Less	Least
Type	Standard	Simple standard	With and without
Replication	Within and between sites	Usually only between sites but can also be within	Between sites only
Levels of treatment	Most	Less	Least
Standardized level of non-experimental variables	Most	Less	Least
Plot size	Smallest	Larger	Usually largest
Who selects technology?	Researcher	Researcher/farmer	Farmer
Who shoulders risk?	Mainly researcher	Researcher/farmer	Mainly farmer
Main discipline of researcher	Mainly technical	Technical/social	Mainly social
Participation by:			
Farmer	Least	More	Most
Researcher:	Most	Less	Least
Numbers of farmers	None	Some	Most
Farmer groups	Least	More	Most
Potential:			
"Yield"	Most	Less	Least
Measurement errors	Least	More	Most
Degree of precision	Highest	Less	Least
Data:			
"Hard" (objective)	Most	Less	Least
"Soft" (subjective)	Least	More	Most
Determination of cause/effect relationships	Easiest	Less easy	Least likely
Incorporation into farming system	Least	More	Most
Evaluation:			
Who by?	Mainly researcher	Researcher/farmer	Mainly farmer
Nature of test	Assesses technical feasibility	Technical feasibility plus economic evaluation	Validity for farmers - practicality, acceptable
Appeal to:			
Researchers	Most	Less	Least
Extension Staff	Usually least	More	Most
Farmers	Least	More	Most
Ease of acceptance of results of trial	Researcher	Researcher/farmer/extension	Farmer

a. There is a degree of subjectivity in some of the entries in the table, but in general they do reflect what is usually the case. In a sense, these expectations also reflect the reasons why the different types of trials are undertaken. In the literature, RMRI trials are sometimes called exploratory trials while RMFI trials are sometimes termed refinement trials.

b. Standard multi-locational trials are also RMRI. Multi-locational trials are differentiated from trials undertaken in a farming systems context in that they are not designed, implemented or evaluated with a farming systems perspective in mind.

c. In a sense we have two types of FMFI trials, those done through research-oriented farmer groups (equivalent to validation trials in the literature) and the more widespread testing done through extension-oriented farmer groups (equivalent to verification trials in the literature).

Source: Slightly modified version of Norman [1989A].

of them together to explain the different treatments after which a number of leading questions are asked to gauge their reactions [Siebert, 1990].

RMRI trials on farmers' fields are analogous to those conducted on the experiment stations. Therefore, the level of testing achieved meets the standards demanded by experiment station-based researchers. However, FMFI trials are the most satisfactory for the farmer, and provide the most practical test of the technology. Due to management and resource constraints, yields or returns will diminish from the RMRI to the FMFI level. The information in Table 2.1 notes the major differences between RMRI work -- mainly the preserve of experiment station researchers -- and RMFI and FMFI trials which emphasize on-farm work. One such difference, for example, is the fact that cause-effect relationships and "hard" (quantitative) objective-type data are more easily obtained from RMRI work; while farmer attitudes and inputs into the research process are more readily obtained from RMFI and FMFI work undertaken on farmers' fields. However, data collected under such formats, particularly at the FMFI level, are likely to be "softer" (more qualitative), and more subjective in nature.[15]

All three types of trials are vitally important in contributing to a well rounded FSR program. Not surprising therefore, we make substantial use of all three types of trials in Botswana. Once one understands the purposes of the different types of trials, it is easier to recognize the complementarities that exist between them, and therefore easier to adopt appropriate criteria in evaluating their worth. For example, it is unreasonable to expect the same low level of variation in the results of FMFI work as in RMRI work. This is because in FMFI work compared with RMRI work, there is much less control on the part of the researcher. As a result in the case of FMFI work, measurement errors are likely to be much higher and the degree of variability in the levels of the non-experimental variables is likely to be greater.

Our experience in undertaking these different types of trials has convinced us of the value that each can make to developing relevant improved crop technologies. However, as discussed elsewhere in the handbook (Sections 5.3.3.1 and 5.3.3.2), we have had much less success in trials with livestock at the farm level. Put simply, the non-experimental variables are even more difficult to control in livestock than in crop work because livestock move and crops don't. As a result RMFI work, in particular, is virtually impossible to achieve, especially with respect to anything that relates to nutrition.

Detailed discussion on the implementation of the different types of trials is found in the later sections of the handbook. However, in this next section three important issues are discussed.

2.4.3 ISSUES IN RMRI WORK

Trials which are to address technical issues, will generally be managed and implemented by researchers (i.e., RMRI level), and entail a standard experimental design (e.g., randomized block, latin square, etc.). However, there are a number of important issues that need to be considered in undertaking such trials:

(a). Should the trial be located on-station or on-farm?

[15]. It is unfortunate that moves towards greater incorporation of the farmer -- the ultimate customer of our work -- in the research/evaluation process usually means a relative increase in "softer" qualitative type of data that is less acceptable to many individuals who are responsible for approving recommendations.

(b). What should be the levels of the experimental, but more particularly, the non-experimental variables, used in the trials?[16]

(c). What evaluation criteria should be used in screening technological options?

Seeking the answers to these questions provides an ideal opportunity for collaboration between station-based and FS researchers.

In general, trials designed to answer cause-effect relationships, should, whenever possible, be carried out on experiment stations. The reasons for this include: lower implementation costs (e.g., in terms of logistics, time, etc.), and potentially better control (e.g., in terms of easier supervision, easier maintenance of **ceteris paribus** conditions, etc). However, there are occasions when conducting such trials on farmers' fields is highly desirable, and sometimes even essential. Such a situation arises if it is felt that the special environmental situation of the experiment station does not provide a realistic environment for testing a technology. Two examples are:

(a). A great deal of herbicide work probably needs to be done on farmers' fields where the weed complex is likely to be very different from that on the experiment station.

(b). The current National Tillage Trial, a collaborative effort between research (on-station and FS workers) and extension, is systematically comparing different tillage treatments designed to increase the amount of water available to plants. In order to cover a range of soil types, the trial is being undertaken on eight different farm sites around the country.

At a minimum, FS teams can provide monitoring data on the technical environment found on farmers' fields, so experiment station researchers can assess environmental differences.

Results from cause-effect type research could perhaps be more relevant if researchers included in the levels of their experimental variables, those that farmers might actually be able to implement.[17] If all levels of input required are too high for the farmers to adopt, then the research may have relatively little relevance without the aid of special support programs for farmers. This applies not only to external inputs like improved seed or fertilizer, but also to internal inputs such as household labor availability.

A closely related consideration is: what should constitute the experimental and non-experimental variables, in technology development work, in researcher managed and implemented trials, particularly on experiment stations? Generally it is not possible to assume that the "non-experimental variables" will be the same for on-station and under farmers' conditions. For example, seedbeds are often better prepared on experiment stations. Varietal testing under such conditions can provide very different results from what would occur if the seedbed preparation more nearly approximated that generally used by farmers.

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[16]. This issue applies primarily to RMRI type work but can also apply to RMFI type trials. In the case of RMFI work, the non-experimental variables should generally reflect the farmers' level since they are responsible for implementing such trials.

[17]. There is, of course, justification for having a range of levels of experimental variables that go beyond what farmers are likely to adopt. This is particularly relevant if it is a design-type experiment used to estimate response curves. Also, this approach can be justified if the results from responses at the higher levels are likely to be used in an attempt to influence planners to change the support systems to enable farmers to use the specific inputs at a higher level.

It is important, **ex ante**, to evaluate whether the levels of the non-experimental variables are likely to influence the relationships being examined between the experimental variables. Special justification should be made if the levels of the non-experimental variables differ significantly from what the farmer is likely to be able to achieve. For example, in the National Tillage Trial, mentioned above, it has been decided to keep the treatments as weed-free as possible so that they do not complicate an analysis of the differences between the tillage treatments in what is a design-type trial. It is recognized, however, that farmers may not be able to create a weed-free environment. Therefore, measurements are being made of the time required in each treatment to keep the plot weed-free.

Finally, evaluation criteria on experiment stations are generally confined to yields per unit area, but this is not always the most relevant criterion to use for the farmer. For example, in Botswana, many empirical studies have shown that labor, particularly during certain peak periods, is often more limiting than land. In farming systems where both land and labor are available, the returns to additional cash inputs might be the most important constraint facing a farmer. In drought prone environments, it may be more appropriate to consider the returns to the net soil-water balance over a whole season. Obviously on small experimental plots, it is often difficult to bring into play other evaluation criteria that are important to farmers. However, whenever possible, consideration of other criteria can be important in ensuring that potentially relevant technologies are not rejected before they can ever be screened at the farm level. FS work can potentially aid experiment station-based staff in deciding on evaluation criteria which adequately reflect farmers' concerns. If such evaluation criteria cannot easily be applied in an experiment station-based environment, it provides justification for complementing or supplementing on-station work with trials on farmers' fields.

Thus, to be truly effective, collaboration between FS teams and component station-based researchers must go beyond adaptive testing by FS teams, and the feeding-back of information to experiment station researchers. Experiment station-based research often involves, implicitly or explicitly, putting components together in packages. The major advantages of these packages include the complementary or synergistic effects between the components. The disadvantages of these packages are the complexities of implementing them, and the likelihood of their being inappropriate for farmers. Thus, when packages are put together, it is important that the components are assembled in a way that they are based on an understanding of the interactions among components, with non-experimental variables being held at the farmer's level. Where packages contain components heavily dependent on interactions, which at the same time compete heavily for resource allocations in the system, an incremental approach to the recommendation and extension of the package is required [Collinson, 1982]. Thus, it is important for experiment station-based researchers and FS teams to work closely together to ascertain what step-wise approach to the adoption of relatively complex technologies could be used. While experiment station-based researchers are often in the best position to identify the interactions between the various components, FS teams can, through collaborative work, help design step-wise approaches for introducing technologies. They can also design fall-back strategies[18] if farmers deviate from the proposed recommendation. Such collaborative work is very important in widening the possible applicability of packages to the needs of larger numbers of farmers.

2.4.4 SUPERIMPOSED TRIALS

Within Botswana, superimposed trials include elements of management by both farmers and researcher, with implementation primarily the responsibility of farmers. Therefore, the trials

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[18]. Elsewhere in the handbook these are called conditional clauses (Section 5.5.3).

generally involve superimposing a degree of research management on a plot or animal being managed, and worked on by the farmer. These trials tend to be single factor experiments, such as looking at the response of fertilizer superimposed directly on a farmer's own plot where he/she is providing both labor and management.

Unlike the other types of trials, discussed earlier, which are implemented according to a plan drawn up at an earlier date; superimposed trials can be pre-planned or unplanned in the sense of responding to a problem that has arisen and by seeking a satisfactory solution.

Advantages of superimposed trials include:

(a). Often they can be undertaken at a lower cost than RMRI or RMFI trials.
(b). A potential exists for responding to research opportunities that arise during the agricultural year.
(c). They can provide an easy way to demonstrate new practices or technologies to farmers.

Two examples of superimposed trials from work in Botswana are as follows:

(a). ***Pre-Planned.*** Experiment station trials had earlier determined the ideal plant populations for sorghum and millet. However, in our work we have found few farmers who achieve the ideal plant population. Therefore we elicited the cooperation of a few farmers who already had standing crops, in order to investigate the practicality of gap filling -- through transplanting -- and thinning, so that farmers could more closely approach the optimum plant population.

(b). ***Unplanned.*** A farmer had a plot that had too many weeds and was not keen on having to use a lot of labor on weeding. In order to demonstrate the benefits of weeding on the eventual yield of the crop, we suggested that he weeded only part of the plot.

In conclusion we do not feel we have yet exploited the full potential of superimposed trials in Botswana, particularly in responding to unanticipated opportunities and as a tool in convincing farmers to change their strategies.

2.5 TYPES OF DATA COLLECTION AND THEIR VALUE

Earlier sections have shown that both technical and socio-economic data are needed in the development of relevant improved technologies for farmers. For example, the time spent on plowing a field is dependent on the type of draft used and the number of hours per day that draft is used. However, it is also determined by a number of technical factors, such as moisture in the soil and the soil type. Unfortunately data collected and analysis undertaken often only reflects either socio-economic or technical data. Earlier sections have implied significant linkages between the two types of variables. Looking at only one aspect does not represent the whole picture. Collecting both types is not always possible, but the limitations of collecting one type of data should be recognized.

2.5.1 COMMON DATA COLLECTION METHODS

The most common methods of collecting data in farming systems work are the following [Kearl, 1976]:

(a). ***Survey Research.*** In this an interviewer records answers to questions. Broadly speaking, there are two types of survey research, based on the number of visits.

i. **One-shot** or **special subject surveys** which involves one or very few visits.

ii. **Multiple-visit (cost-route) surveys**, which involve multiple or frequent visits by an enumerator or interviewer. These are done to combat problems of recall and to describe changing situations and operations. The use of **farm record (account) books** is a type of multiple-visit survey.

(b). ***Observation.*** Once again there are two major types based on the degree of participation of the interviewer. In the case of **participant observation**, the person being observed and the researcher have a very close relationship and the latter may help the former in his/her tasks (i.e., the classical anthropological approach), while with **non-participant observation** the researcher observes the respondent but does not help him/her with the tasks.

(c). ***Direct Measurement.*** In this case the researcher or his/her staff record measures directly (e.g., field sizes, yields, soil moisture, weed burdens, etc.).

(d). ***Group Interviews.*** Here a group of respondents are interviewed together and often an effort is made to arrive at an average or agreement.

A number of factors influence what method or methods are used. Some of these are as follows:

(a). The discipline of the researcher(s). For example, in farming systems type work in Botswana, economists have tended to concentrate on methods (a) and (b) above, while the major thrust of technical scientists has been on method (c).

(b). The availability of private, public or institutional records in the study area. Related to the records being available, is the level of literacy in the area. For example, farm record (account) books are likely to have little value where the level of literacy is low.

(c). Financial resources for the study.

(d). The potential for collecting satisfactory data with enumerators of limited educational levels.

(e). Time available to undertake the study.

(f). Whether the type of farming system on which the study is to be undertaken is complex or simple (e.g., year round versus seasonal farming, mixtures versus sole stands of crops, etc.).

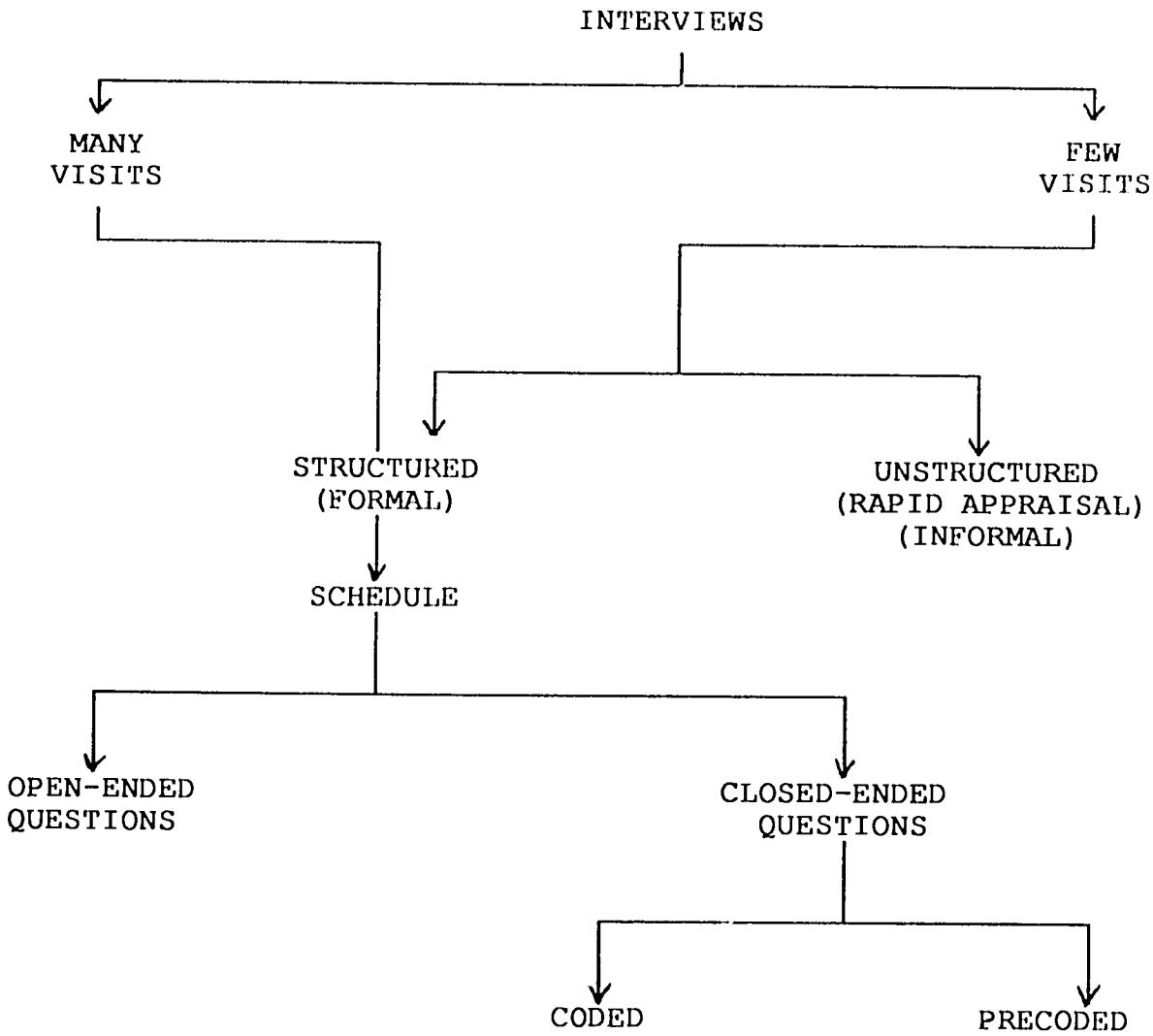
(g). The potential of the method for reducing:
i. Sampling error. Basically this means that a sample, chosen from a population, does not perfectly represent the population.
ii. Measurement error. This relates to mistakes in the enumeration and analysis of data.

(h). The type of data required (Figure 2.2), based on:
i. "Single point" to "continuous" continuum (relating to an event or activity that

FIGURE 2.2: TYPES OF DATA

	REGISTERED	NON-REGISTERED
SINGLE POINT	FOR EXAMPLE AMOUNT OF FERTILIZER PURCHASED	
CONTINUOUS		FOR EXAMPLE LABOR INPUTS BY MONTH AND OPERATION

FIGURE 2.3: TYPES OF SURVEYS (INTERVIEWS)



Source: Modified from Kearl [1976].

occurs over a brief time span, as against one that has much longer duration).

ii. "Registered" to "non-registered" continuum (relating to an event whose occurrence and dimensions leave a written record or distinct and vivid recollection as against one less likely to be recorded or remembered).

Usually measurement errors are lower with single point registered data (when memory recall would be good) and higher with continuous non-registered data (when memory recall would be bad).

It is possible to evaluate the methods of data collection in terms of the above factors. In Table 2.2 the significance of each factor or operational constraint with respect to each method is given a ranking of 1 to 6, with "1" indicating a very favorable ranking and "6" indicating a very unfavorable ranking.

Because of operational constraints a combination of strategies (e.g., multiple-visit survey and direct measurement) is often used. The results in Table 2.2 show that no one method of data collection is basically superior in minimizing operational constraints.

Careful thinking is required about how accurately the data needs to be collected. When making a decision about how the data are to be collected, keep in mind that the costs (e.g., financial and time) associated with a data collection method should be comparable to the type of information sought. For example, multiple-visit surveys for quantifying actual seasonal labor flows are expensive and require a good deal of time. A rough estimate based on a much cheaper and quicker one-shot survey may in fact be sufficient for the purpose required. It is important to consider whether a more accurate measurement would improve the understanding enough, to justify giving up other opportunities such as working with more farming families? Depending on the type of data being collected, measurement errors are reduced with more frequent interviewing techniques, while sampling errors are reduced by involving larger numbers of farmers. Unfortunately, in farming systems work we often have limited resources and as a result have to make a trade-off between these two errors.

Related to the above and to efficiency is the idea that sometimes cheaper qualitative type data may provide sufficient understanding rather than having to collect expensive quantitative type data. Qualitative information can include not only attitudinal information, but information on the relative labor requirements of different operations, etc. Limiting quantification to key characteristics reduces the cost involved in collecting data.

2.5.2 DIFFERENT TYPES OF INTERVIEWS

There are many ways of collecting data. Figure 2.3 illustrates some of the different ways used in farming systems work for collecting data in interviews -- a method which is used a great deal. All these methods have their particular place:

(a). The ***interview schedule*** has questions or items which are asked and filled in by the interviewer. This is usually done in a face-to-face situation.

(b). ***Structured (formal) and unstructured (informal) interviews*** are differentiated by the help given by the interviewer. A structured interview is one in which similar help is given to all respondents, while unstructured interviews can result in different help being given to different respondents.

TABLE 2.2: EVALUATION OF DATA COLLECTION STRATEGIES IN TERMS OF OPERATIONAL CONSTRAINTS[a]

CONSTRAINTS	STRATEGIES				
	SURVEY		OBSERVATION	DIRECT MEASUREMENTS	GROUP INTERVIEWS
	FEW VISITS	MANY VISITS			
Finances	2	3	6	5	1
Ability of enumerators	3	3	6	5	4
Time required	2	3	6	5	1
Type of system:					
Simple	2	1	1	1	2
Complex	5	2	1	1	6
Errors:					
Sampling	1[b]	3[b]	5[c]	5[c]	6[c]
Measurement:					
SPRD[d]	3	1	1	3	
CNRD[e]	6	2	1	1	5

a. Evaluation of data collection strategies in terms of cost per unit with respect to various operations (1 = lowest cost per unit, 6 = highest).
b. Evaluated in terms of ability to reduce sampling error.
c. Evaluated in terms of ability to specify sampling error.
d. Single-point registered data.
e. Continuous non-registered data.

Source: Kearl [1976].

In practice, structured interviews involve collecting information on the same topics from all respondents. In contrast, unstructured interviews, involve collecting different information on different topics from different respondents. Also unlike structured interviews, where the information to be collected is decided prior to the interview, in unstructured interviews the types of information collected will tend to be partly stimulated by interaction between the interviewer and respondent.

(c). The questions on the schedules asked in the structured interviews can be either ***open-ended*** (i.e., where the respondents give their own answers) or ***closed-ended*** (i.e., where the respondents choose from a limited number of responses).

(d). ***Coding*** is part of the process of converting questionnaire or schedule responses into a form ready for data analysis. This can take place at two stages: either as ***pre-coding*** during the interviewing stage or ***general coding*** after the data are collected. With a pre-coded schedule enumerators can, during interviewing, enter the actual codes which are later to be entered directly into the computer.

As a general rule it is important to find ways of improving the efficiency of the data collection, processing and analysis links. For frequent interviewing surveys, processing should start while data are still being collected. Also, all surveys, no matter how they are undertaken, need to be designed to facilitate quick processing so as to simplify the transfer of data to computer-based systems. Structured interviews, using schedules with pre-coded, closed-ended questions are potentially more efficient in this regard and whenever possible should be used, especially if:

(a). The researchers themselves are not conducting the interviews.
(b). The enumerators are not particularly well-qualified.
(c). Comparative analysis, such as cross tabulation, etc., is to be undertaken.

2.6 SELECTING VILLAGES AND FARMERS

The process of selecting on-farm research sites begins with the selection of the research region, and in general, includes the following steps:

(a). Selection of target area; usually by decision makers.
(b). Division of the target area into sub-areas according to characteristics relevant to the particular project; done by the farming systems team.
(c). The farming systems team selects the research area or areas within the target area.
(d). Representative villages are selected, by the team, within the research area.
(e). Team selects representative farmers within the villages.
(f). Farmer and team select trial sites on farmer's fields.

This section discusses steps (a) through (e) with particular emphasis on steps (d) and (e). Step (f), selection of on-farm trial sites, is covered later (Section 8.2.1).

2.6.1 SELECTION OF TARGET AND RESEARCH AREAS

Shaner et al., [1982: p. 43] suggest that a target area may be selected for two basic reasons:

(a). To meet the needs of the people living there and\or
(b). To take advantage of its agricultural potential.

If conditions within the target area vary substantially, it can be subdivided on the basis of similar physical, biological, socio-economic, and farming systems characteristics.

Generally the selection of a target area for a farming systems program is made by national decision makers, usually in the Ministry of Agriculture. Criteria considered in the selection depends on the purpose for establishing the farming systems project or program. The criteria used may depend on whether the farming systems effort is to be a project dealing with a specific part of the country or specific agricultural problem, such as low productivity in rainfed agriculture; or if it is to be an on-going segment of the national research organization, dedicated to on-farm research. Whatever the purpose of the farming systems effort, the criteria considered may include: compatibility with national policy and priorities; and/or be based on physical limitations or problems such as poor water availability and distribution, erodible slopes, flooding, or animal disease.

Answers to the following types of questions may assist decision makers in selecting target areas [Shaner et al., 1982: p.45]:

(a). Is the target area or sub-area large and relatively similar in those environmental characteristics that have the most bearing on potential research results? If so, the farming system team can apply the research results broadly and meaningfully within the target area.

(b). Is the target area similar to other areas? If so, some of the technologies developed in the target area can be used in other areas.

(c). Does the area have the potential for rapid pay-off from farming systems work? Factors that often determine the potential are:

i. Physical and biological conditions,
ii. Markets and infrastructure,

iii. Available technology, and
iv. Farmers' willingness to accept innovation.

(d). Do the area's environmental conditions facilitate application of technologies developed elsewhere? If so, the farming systems process could be greatly shortened.

(e). What are some of the cost factors? For example, is the target area now served by existing governmental programs or private institutions? If so, cooperation with such programs or institutions could enable the farming systems team to accomplish more, reduce costs, and/or save time.

After the target area has been chosen, the farming systems team usually selects a research area or areas within the target area. The following factors may be important considerations in defining a target area [Shaner et al., 1982: pp. 52-53]:

(a). ***Representativeness Of The Target Area.*** This is usually the most important criterion for research area selection. It must be representative of the target area or sub-areas with respect to environmental conditions -- that is, physical, biological, and socio-economic -- and the farming systems practiced.

(b). ***Accessibility.*** The ability to travel easily to all parts of the research area will generally enhance cooperation between the research team and farmers, allow for easy distribution of inputs and access to markets, and reduce the team's operating costs.

(c). ***Existence Of A Nearby Agricultural Research Station.*** Research areas located close to research stations generally have more cooperation between on-station and off-station researchers, and can provide a more integrated approach to the overall research program.

(d). ***Cooperation Of Farmer Contact Agencies And Leader Support.*** Good working relationships with agencies operating directly with farmers, such as extension and the National Development Bank, can increase the effectiveness of the farming systems team. This is particularly important when such agencies must be relied upon to provide information, inputs, credit, etc. Help and support from formal and informal leaders, at the national and local levels, can be critical to the success of the farming systems program.

In order to make an informed selection of a research area within a target area, a good deal of information must be available to the decision makers. Table 2.3 identifies many of the data categories necessary for research area selection. Much of these data can be collected by the farming systems team from secondary sources such as existing reports, aerial photographs, etc. Additional information may be obtained by spot visits in the proposed research areas, and/or more formalized reconnaissance surveys. The final decision about the research area often involves input from national, regional, district and local level government officials, as well as from the farming systems team. Research area selection may take as little as two weeks when relevant data are readily available, or it may take six weeks or longer when several areas are being considered, secondary data are scarce, or there are other problems.

2.6.2 SELECTION OF VILLAGES

Village selection is usually made by the farming systems team often after consultation with, and advice from, the Regional Agricultural Officer, the District Agricultural Officer, and

other informed regional, district and local officials.

Farming systems teams will generally use several criteria in selecting villages within the research area. These may include factors considered in choosing the research area (discussed

TABLE 2.3: DATA CATEGORIES FOR RESEARCH AREA SELECTION

PHYSICAL ENVIRONMENT	
Climate:	Rainfall, temperature, wind, sunny days
Soil:	Physical, chemical, hydrological conditions
Topography:	Slope, flood plain
Irrigation:	Water source and quality, means and frequency of delivery, on-farm practices
BIOLOGICAL ENVIRONMENT	
	Weeds, insects, diseases, birds, rodents, crop yields
SOCIO-ECONOMIC ENVIRONMENT	
Resource availability:	Land, labor, cash, type and source of traction
Infrastructure:	Supply of farm inputs, markets for farm outputs, transportation
Market data:	Prices of farm inputs and commodities, traders
Socio-cultural characteristics:	Land tenure and inheritance systems, sexual division of labor in agriculture, religious beliefs concerning agriculture, openness to change
Political and economic structure:	National regulations, community groups, patron-client relationships, cooperatives
PRODUCTION SYSTEMS AND LAND USE	
	Major crops and livestock, cropping patterns, livestock characteristics, management practices

Source: Based on table found in Shaner et al., [1982: p. 54].

above). Some of the more important considerations are:

(a). ***Representativeness.*** This is of primary importance because if the villages selected for research are not representative of the target and research areas, technologies developed, which are applicable to these villages, may not be transferable to the larger research and target areas.

(b). ***Logistical Considerations.*** These considerations are particularly important. The number of villages to be selected for research activities may well be limited by; the number of field staff who will be available to the farming systems team, the ease of access to the chosen villages, their proximity to one another, etc. There may be trade-offs between the desirability of selecting certain villages for representativeness or other factors, and the need to limit village numbers or locations due to resource constraints on the farming systems team.

(c). ***Characteristics Of The Village.*** In addition to being representative in the physical, biological and socio-economic sense, some other characteristics may be important, such as; availability of markets, the presence of an agricultural demonstrator, etc.

(d). ***Other Factors.*** Other factors may be considered in a particular village selection. For example, if several villages are to be selected it may be desirable to select a "traditional" village, a "progressive" village and a village that is in "transition" due to its location on a main roadway. The team's assessment of local support, both by local officials and by farmers, may also be important.

The selection of villages is based on much of the same data used to identify the research area (Table 2.3). This information is collected from secondary sources, from discussions with extension and other government officials, and by direct observation. Background

information must be relatively recent to be of most value. Information from extension personnel who have worked in the area for five or more years, and from leaders (formal or informal) who have lived in the village for 10 years or more, is probably most valuable. Team members should do at least a "wind-screen" survey of potential villages. More satisfactory results may be obtained from interviews with key community members and officials, and possibly from a more formalized rapid reconnaissance survey. The assessment of local support can take place during these visits.

When the information is collected, the team is in a position to make a decision. If there are numerous villages being considered, a matrix of each village's characteristics, according to key factors, can be constructed. For example, what is the average land holding in the village. These can then be ranked in relation to the mean for the target area. After all factors are ranked for each village, the rankings can be totaled and, based on the factors considered, the village with the lowest total is the most representative of the target area. This type of assessment of quantitative factors may be of assistance to the farming systems team in making village selection, but must be modified in light of qualitative information available to them. The existence of already defined recommendation domains can greatly reduce the amount of effort necessary, and implies that there is a good deal of existing (ex ante) knowledge of the area.

Once a research village (or villages) is selected, it will most likely be used during the diagnostic/design phase of the farming systems research, and also during the testing phase. This is particularly true if the field staff are permanently stationed in the village as housing, etc., may have been provided by the project. There are reasons for changing villages during the life of a farming systems project. These might include:

(a). The discovery that the village is not representative, or is not representative in certain key characteristics.
(b). That past research activities have changed the character of the farmers and the village, so the present research activities are not taking place in a "typical" environment.
(c). A change in the mandate of the team, necessitating a change in villages.
(d). A change in the resources available to the farming systems team, requiring a corresponding change in team activities.
(e). Philosophical reasons for changing villages, such as the desire to provide exposure of the research to a larger number of farmers.

2.6.3 SELECTION OF COOPERATING FARMERS

The final step in identifying individuals to be interviewed, or individual fields for experimental purposes, is the selection of cooperating farmers.[19] Gedeno defines a representative farmer as "a member of a group of farmers within a recommendation domain, having similar circumstances for which one can make more or less the same recommendations" [Gedeno, 1987: p. 12].

In selecting farmers to participate in formal interviews or in hosting trials, the farming systems team may use several criteria. As with the selection of research areas and research villages, the most important criterion for choosing farmers is their representativeness. The

[19]. The cooperating unit may be a dwelling, a farming household, or specific members within a household. See Behnke and Kerven [1983] for a discussion of the issues involved in choosing an appropriate unit.

farmers selected must be as representative of the area's average farmer as possible, to allow for extensive use of the results. While it is important that the farmers chosen be representative of area farmers, they may also be chosen to be representative of farmers in a particular recommendation domain or target group. In the latter situation, farmers with certain characteristics are preferred. These characteristics may be: the gender of the head of the household, a wealth factor (usually number of cattle owned), the type of draft used and whether the draft is owned, and specific characteristics of the type of land farmed or animals owned. These factors can be used to stratify a sample to ensure that there is representation by both male and female heads of households, by wealthy and poor farmers, etc.

Behnke and Kerven [1983] describe the problem of using a farm household (i.e., a unit composed of multiple dwelling units, with their own lands, and linked by family and/or other ties) as the research unit. The choice of an appropriate research unit may be an important consideration in selecting cooperating farmers. The dwelling unit may be more appropriate than an entire family compound if members of the dwelling units operate quasi-independently in their agricultural activities. This question is closely related to the one of intra-household division of labor and decision making. For some studies, the head of household may not be the most appropriate cooperator, particularly if some other family member has responsibility for, and decision making power over, the particular activities of interest.

The interest, willingness, and ability of farmers to cooperate are also important selection criteria. Farmers may be interested and willing to cooperate, but they may not have the resources to participate, or they may face conflicts in the use of resources, if they participate. There may also be a willingness on the part of the head of household to participate, but not from some other members of the family who will face an adverse situation if the family participates in the farming systems work. Thus teams selecting farmer participants must make sure that all members of the household, who may be affected by the households participation, are willing to cooperate [Shaner et al., 1982: p. 116].

Logistical considerations are also important in selecting trial or interview participants. To facilitate visiting participants, particularly at their lands areas, the team may choose to select farmers from one or two groupings of lands areas, or select participants to reflect groupings or communities within the village. Sutherland [1988: pp. 7-8] suggests that farmers belong to a community within the village that may be linked by family, social and/or economic ties. Participants in such communities are generally located in the same general geographic area within the village, and selecting several community members will not only reduce logistical problems, but can provide additional information on linkages between households for shared draft, work, etc.

Once the farming systems team decides on the criteria for farmer selection which are most appropriate for their situation, they must contact the potential cooperators, and make their choice of cooperators. Most farmers will be somewhat suspicious of, and curious about, researchers entering their village. Due to the complicated social structure of most small villages, it is often important to identify village leaders and seek their support or approval. Village leaders who may provide the necessary or helpful support include traditional leaders, such as the village headman, and community leaders (e.g., an influential school teacher). As Shaner et al., [1982: p. 278] point out, gaining the support of such community leaders will:

(a). Reassure the farmers of the team's intentions, and thereby reduces farmers' suspicions, and encourages them to cooperate with the team.
(b). Help elicit meaningful answers from survey participants.
(c). Allow the team to check the accuracy of the interview data with the leaders.

Researchers can gain local leadership support by Shaner et al., [1982: p. 278]:

(a). Explaining the project.
(b). Emphasizing that in surveys, farmers' answers will be kept confidential.
(c). Stressing that no names or specific individual information will be given to other government agencies.
(d). Explaining how farmers will be selected.
(e). Keeping the leaders informed on the project's progress.

Farmers to be surveyed or to host trials are usually selected from some kind of a list of farmers in the village. Devising such a list is often a challenge. Problems with respect to this are discussed later (Section 7.3.2.5).

Once farming systems teams have selected a group of farmers to participate in a survey or to participate in an on-farm trials program, there is a tendency to work with the same groups over a period of years. This has both positive and negative effects. Working with the same farmers provides information over time, which is useful in identifying changes in the system. On the other hand, the farmers may become atypical of the average farmer in the area due to their contact with the farming systems team. Thus, it may be important to change the group of cooperating farmers for some surveys (particularly single purpose surveys) and for some trials work. Whether a change in cooperators is necessary depends on the objectives of the trial or survey, and numerous other factors such as whether the farmers are still representative. It is also important to consider updating the list of farmers from which cooperators are chosen, either randomly or purposively. This is particularly relevant if the list is several years old, and if there has been substantial in- or out-migration in the village.

Finally, in selecting farmers for on-farm trials, it is important to match farmers with trials that suit their farming framework in terms of resources, preferences, and management abilities. How well a farmer will carry through on a trial may depend on perceived benefits associated with the trial. Thus, the more appropriate the trial is to the farmer's circumstances, the better the chances that it will be completed.

2.7 USEFUL REFERENCES

Section 2.1:

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Section 2.2:

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Section 2.3:

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Shaner, Philipp and Schmehl, 1982, p. 96.

Section 2.5:

Caldwell and Walecka, 1987: pp. 272-282.
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Section 2.6:

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CHAPTER 3: LINKAGES

3.1 FARMER PARTICIPATION

3.1.1 IMPORTANCE OF FARMER PARTICIPATION

There are a number of reasons why it is important to get farmers to participate in the various activities of FSW. Some of the reasons for obtaining their participation can be summarized as follows:

(a). If the technologies or support systems being disseminated to farmers are not accepted by them -- the ultimate consumers -- then all the work of other "actors" in the agriculture development process is wasted.

(b). Since farmers stand to lose or gain the most from adopting changes proposed by researchers, extension, development agencies and planners, they should have a voice in developing a product that they want.

(c). In relation to (b) above, farmers should be given the opportunity to articulate their needs so that they can be addressed by researchers, planners and development agencies.

(d). Farmers can contribute constructively to the design of relevant technologies and policy/support systems by researchers and planners because of their intimate knowledge about:

i. The technical environment (physical conditions) on their farms such as soils, water movement, weed complexes, etc.

ii. The human environment or the quantity and quality of the resources they have at their disposal such as labor, land, capital (draft, equipment, etc.), and managerial expertise.

iii. The complexity of their farming systems in devoting their limited inputs (resources) to growing a number of crops, to often keeping more than one type of livestock, and sometimes also pursuing an off-farm occupation.

iv. The heterogeneity of farming households with respect to differentiation in their technical and human environment, which as a result gives rise to differences in the farming systems they adopt and the constraints they face.

(e). Farmers through participating in trials and studies can themselves learn about technologies and other changes that are being proposed.

(f). Farmers can help -- as a result of activities specified above -- in evaluating proposed new technologies, and under certain circumstances in evaluating development/support systems.

Although most people in FS work recognize these types of contributions that farmers can make, there has often been a difference between what is desirable and what in fact takes

place. A number of people have criticized the fact that FS teams do not get farmers sufficiently involved in their work programs.[1]

Even though we don't claim to have developed an ideal model for ensuring farmer participation, we do feel that in Botswana, progress has been made in making sure they do have a positive impact on the work program. The following two sections are devoted to a discussion on some of the points to bear in mind when approaching farmers to get their cooperation, and to a review of the types and levels of collaboration that are possible within the Botswana setting.

3.1.2 APPROACHING THE FARMER

Obviously, in order to benefit from any type of collaboration with farmers, it is important to develop a good relationship with them. The initial approach to the farmer, and the relationship that develops over time, are critical elements in creating an environment conducive to collaboration. Some of the points that are important in developing a good relationship, are as follows:

(a). It is important for FS team members to respect the customs of the village, and to respect individual farmers with whom they are working.

(b). Related to the issue of respect is the need for a collegiate or partnership type of relationship to develop between the FS workers and farmers. So often, because of differences in educational levels, a paternalistic or master/servant type of relationship develops. If this type of relationship is formed then the development of constructive collaboration will be difficult. Under these conditions, researchers will only offer to farmers those technologies they feel confident about. However, if a partnership type of relationship develops, then an attitude of joint investigation can flourish allowing technologies to be tested with farmers which are not completely proven. Additionally, under these particular circumstances, no blame is likely to be apportioned to the FS worker if the trial does not succeed.

(c). Be friendly and be willing to listen and talk about other matters than just the work program.

(d). When discussing matters with farmers, be patient and take time to repeat plans, ideas and instructions. It is also important to frequently check on what progress had been made. Any disappointments that result from farmers not collaborating to the degree anticipated, should be transmitted to the farmers in a constructive rather than a destructive manner. Try and learn from such experiences and plan in the future, if possible, to make changes that will avoid these happening again.

(e) Related to the issue of disappointment, it is important to be reasonable about the level of cooperation and collaboration requested of the farmer. For example, efforts should be made to avoid becoming over committed and putting him/her into a high risk situation.

[1]. For example, see Chambers and Jiggins [1987], Chambers and Ghildyal [1985]. Recent publications that give some very constructive ideas on how to involve farmers in the research process are Farrington and Martin [1988], and Chambers, Pacey and Thrupp [1989].

(f). Efforts should be made to ensure that both farmers and researchers know exactly what has been agreed to. In other words, a type of contract -- which may simply be verbal in nature -- needs to be agreed upon. Also care should be taken by FS team members to deliver on any promises of help that they make, and to be very careful about building any reward systems into the contract terms. In general, reward or insurance terms such as guaranteeing a certain level of return should be avoided particularly in trials at the FMFI level.

As can be concluded from the above list, the objective is to develop an open communication system with the farmers, based on full knowledge, and in a partnership mode with feelings of mutual respect. If these conditions are not fulfilled, then any type of collaboration with farmers will be limited.

3.1.3 TYPES OF COOPERATION

Table 3.1 notes the types of strategies we have used in Botswana, over the years, to bring about cooperative interaction between FS teams and farmers. As the table indicates, the strategies involve different degrees of commitment on the part of researchers and farmers. Obviously to maximize the input by farmers, a high degree of commitment on their part is most desirable, e.g., FMFI trials, participation in farmer groups, etc. Nevertheless, as was discussed earlier (Section 2.4.2), the degree to which such a commitment is necessary will depend on the research objective. For example, the farmer's role in RMRI trials is minimal, while responding to survey questions only requires time. Details on how the various strategies in Table 3.1 are implemented in Botswana are presented in other sections in the handbook.

TABLE 3.1: TYPES OF COOPERATION BETWEEN FARMERS AND FSR TEAMS

NATURE OF COOPERATION	DEGREE OF COMMITMENT		WHAT FARMER HAS TO COMMIT
	FARMER	RESEARCHER	
A. Mainly dialogue			
Surveys	Low	Medium	A little time
Opinions on RMRI trials[a]	Low	Low	A little time
Farmer field days	Low	Low	A little time, maybe some money
B. Trial participation			
RMFI	Some	Some	Land, labor
FMFI	Much	Low	Land, labor, management
C. Farmer groups:			
Researcher-oriented:			
Mahalapye[b]	Much	Some	Time, land, labor, maybe management
Francistown[c]	Much	Much	Time, land, labor, management
Extension-oriented	Much	Low	Time, land, labor, management

a. Informal groups of farmers have been brought together in the Mahalapye area to react to specific questions about the different treatments being tested in the trial. This is done in the field when differences in the various treatments are visible.

b. Consists of both RMFI and FMFI trials, with an attempt to reduce the intensity of researcher input by having fewer meetings than in the case of Francistown area. However, undoubtedly this reduces the farmer-to-farmer interaction and farmer-researcher interaction in a group situation.

c. Consists of FMFI trials and monthly farmer group meetings to promote farmer-to-farmer interaction and farmer-research interaction.

3.2 LINKS TO ON-STATION RESEARCH

3.2.1 SIGNIFICANCE OF LINK

Earlier (Section 1.1.4) it was argued that FSR work is not a substitute for on-station work. Rather the two are complementary to each other and both types of research are required. The reasons for this are as follows:

(a). The results of on-station research can provide farming systems teams with potential solutions (technologies) which may help in solving identified farmer problems.

(b). Through on-farm work FSR workers can relay back to experiment station-based researchers, farmer needs and pressing problems that can be used in setting priorities for station-based research and experimentation. There are a large number of diagrams that illustrate the constructive interaction that should be occurring between FSR work and experiment station-based research.[2]

Not surprisingly, as was also discussed earlier (see Section 1.3.3) there has been a recent reorganization of the research process in the Department of Agricultural Research that better reflects the constructive interaction that can occur between FSR and experiment station-based research.

3.2.2 COLLABORATION BETWEEN ON-FARM AND STATION-BASED RESEARCH

Given the importance of interaction between FSR and experiment station-based research in Botswana we pursue a number of strategies to try to ensure that constructive interaction takes place. Some of the strategies that we have used to date are listed in Table 3.2. As can be seen, there are varying degrees of collaboration. Also there is some potential overlap between the various activities. For example, participation in the research program team meetings can result in visits by station-based research scientists to the field to visit plots, address farmer groups about specific technologies, and cooperate in joint trials.

Obviously collaborative work represents the most intensive form of interaction between on-station and on-farm research. The highest level of collaboration is where there is joint responsibility on specific trials or surveys. This is the most desirable form as it eliminates the division between them (station-based researchers) and us (FSR workers). As a result of this collaboration, there is less chance of miscommunication, and a greater chance that the results will be accepted by all concerned.

Over the years that the FSR teams have been operating in Botswana there has been an increasing emphasis on collaborative work in addition to improvements in communication and joint visitation. We expect collaborative work to be further emphasized as the program research teams become more effective and institutionalized. This we believe is an important development as it will help to blur the distinction between on-farm and on-station research, and to contribute to the development of more positive interaction.

See, for example, one originally developed by Collinson which is in Caldwell and Walecka [1987: p. 50]. Another one which is very similar is given in CIMMYT [1988A: p. 2].

TABLE 3.2: TYPES OF COOPERATION BETWEEN EXPERIMENT STATION-BASED RESEARCHER TEAMS AND FSR WORKERS

NATURE OF COOPERATION	----- DEGREE OF COMMITMENT ----- STATION-BASED RESEARCHER	FSR RESEARCHER
A. Mainly Communication:		
Circulating papers on work program and results to interested parties	Low	Low
Research program team meetings	Some	Some
B. Visits:		
By station-based researchers to farmers' fields, to address farmer groups, to give advice in identifying and solving problems, etc. -- usually at the invitation of FSR workers	Some	Low
By FSR workers to experiment station-based researchers	Low	Some
C. Collaborative work:		
Surveys undertaken by FSR researchers to address specific issues raised by station-based researchers -- sometimes latter help in design, implementation, etc.	Some	Much
Farmer evaluation of technologies station-based researchers are interested in, e.g., crop varieties, implements, etc.	Some	Much
RMRI trials undertaken on experiment station to address issues raised by FSR workers.	Much	Low
Joint responsibility for designing, implementing and evaluating on-farm trials by FSR and station-based researchers.	Much	Much

3.3 EXTENSION LINKAGES

3.3.1 IMPORTANCE OF LINKAGE

Earlier the significance of extension as a contributor to the agricultural development process was mentioned. The value of the interaction between FSR workers and extension staff can be summarized as follows:

(a). Extension staff possess substantial knowledge about the area where they are posted, and know many of the farmers personally. This local knowledge is invaluable to FSR teams in their diagnostic, design and esting work.

(b). FSR workers interact with small numbers of farmers -- hopefully representative of a much larger number of farmers -- while extension staff have a mandate to work with all farmers. In a sense, the extension service provides a conduit for FSR teams to reach farmers as a whole. Therefore interaction between FSR teams and extension staff can help provide a multiplier effect for FSR work, can assist in providing extension staff with relevant messages to disseminate, and can help extension staff in developing appropriate methods and systems for disseminating technologies to farmers.

Thus extension staff can make constructive contributions at all stages of the FSR process, although as we indicated in Figure 2.1, the nature and type of contribution will vary.

3.3.2 LINKAGE ACTIVITIES

In Botswana, we try and encourage as much interaction as possible throughout the various stages. However, we recognize that extension participation in the activities noted under (a)

above (Section 3.3.1) are often limited due to other commitments[3]. There are, however, many benefits to interaction at this level that go beyond those listed. For example, extension staff can greatly facilitate the selection of areas and farmers[4]. The interaction provides exposure to and an understanding of the proposed technology which in turn assists in the dissemination process. Also, if the testing yields promising results, the plots, in a sense, act as an informal demonstration.

However, activities described in (b) above (Section 3.3.1) relate much more to the primary duties of extension staff and therefore provide a much more fertile and likely ground for strong interaction with FSR workers. In fact, these types of activities have been the ones which have developed most rapidly during the last few years in Botswana.

Like most countries, Botswana is faced with a situation where the MOA is divided into a number of departments, e.g., research, extension, planning, etc. Control is exerted through these departments and is, of necessity, "vertical" in direction. Since FSR teams in Botswana are located within DAR, it is relatively easy to formalize and strengthen linkages with other personnel in the department. However, the development of "horizontal" linkages with extension staff in DAFS is more challenging since they are more difficult to formalize. There are, however, two positive strategies being used to encourage coordination between research and extension in Botswana. These are:

(a). At the national level, a Research Extension Liaison Office (RELO) which may be relocated under the office of the Deputy Permanent Secretary, has an important potential role to play not only in improving interaction between DAR and DAFS at the national level, but also between research and extension in the various regions.

(b). Within the regions, mutual recognition on the part of extension and research (i.e., FSR) personnel of the benefits of interaction has led to the development of informal linkages which have received the support of the leadership in DAFS and DAR. Over time it would be desirable for these linkages to be viewed as a legitimate part of the job descriptions of research and extension personnel, thereby in essence, formalizing the linkages and moving away from the more informal linkages which have been based on informal relationships.

Some of the linkages that have been established between FSR teams and extension, in Botswana, are described in Table 3.3. The number and range of collaborative activities have increased over the years. These activities have involved varying levels of commitment, and have often resulted in promoting further collaborative efforts. Once again there is considerable potential for the overlapping of activities. For example, consultation activities have lead to collaborative activities, while FSR participation on a supportive basis in dissemination-type activities may lead to new items for the research agenda.

In recent years emphasis has been given to pursuing activities requiring higher levels of commitment from both research and extension (i.e., collaborative and dissemination-type activities). We support this and expect this trend to continue.

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[3]. As was indicated earlier (see Section 1.3.2), MDP and FSSR have, until recently, been located in DAFS. As a result they have found it much easier to establish and maintain linkages with extension staff.

[4]. One cautionary note is that care is needed to ensure that farmers suggested by the extension staff, do not only represent progressive or wealthier farmers, but do reflect the target farmers.

3.3.3 FSR ROLE IN TECHNOLOGY TRANSFER

As was mentioned earlier, the farmer is the ultimate client of the improved technologies resulting from trials -- both on-station and on-farm. Naturally, the best evaluation is spontaneous adoption of potentially improved technologies tested by farmers in on-farm trials. Various types of indices have been developed to measure this. One type of adoption index, called the index of acceptability, will be discussed in later in the handbook (see Section 11.5.2).

TABLE 3.3: TYPES OF COOPERATION BETWEEN EXTENSION STAFF AND FS TEAMS

NATURE OF COOPERATION	- DEGREE OF COMMITMENT -- EXTENSION	FS WORKER
A. Consultation:		
Discussion of work program -- proposals and results -- with regional extension staff and other interested parties in the region, e.g., ALDEP, NGOs,[a] etc.	Low	Some
Attendance, when desirable, by FS staff at regional extension meetings and district monthly management meetings	Much	Low
B. Visits:		
Local extension staff help in organizing village kgotla meetings to present proposals and results of FS work programs	Some	Some
By senior extension staff to trials undertaken by FS teams	Low	Some
Attendance by extension staff at farmer field days -- sometimes help in organization	Low	Some
C. Work Program Collaboration:		
Secondment of locally stationed extension staff to the FS teams to help in implementing all the activities of the FS teams	Much	Some
Joint planning, implementation and evaluation of trials, e.g., National Tillage Trials	Much	Much
C. Dissemination:		
Participation by FS staff in in-service training courses for extension staff	Much	Some
Supportive role by FS staff in organizing competitions at agricultural shows to encourage adoption of improved technologies	Much	Some
Supportive role by FS staff in extension-oriented farmer groups	Much	Some
Supportive role by FS staff in helping extension staff in "hands-on" training of farmers to adopt improved technologies	Much	Some

a. Non-Governmental Organizations, e.g., Development Trusts, Brigades, etc.

The issue of spontaneous adoption raises some questions about the degree to which FSR workers should actively engage in this mode of evaluation:

(a). How involved should FSR workers become in training farmers in the details of the improved technology so that they can better perceive and reap the benefits from its adoption?

(b). Should aggressive strategies be developed by FSR workers to disseminate the improved technology before it has been approved by the Recommendations Committee at headquarters?

To date we have attempted to resolve these issues in the following manner:

(a). We recognize that because of our institutional linkage in DAR, our primary role must be in research -- in other words, the development of technology rather than its

dissemination.

(b). However, we recognize that, because of the multiple clients who interact with FSR workers, we do have a responsibility to help extension/development agency staff and farmers to develop processes that will improve the efficiency of dissemination and adoption. In this sense, we see our role as being supportive and catalytic rather than being one of leadership.

(c). We are obviously happy to see the spontaneous adoption of a technology as a result of our efforts in the villages where we work. However, we recognize that more complex technologies, and technologies that require substantial changes on the part of farmers, will not be readily adopted by farmers without appropriate training programs, and availability of the relevant external inputs (e.g., equipment, improved seed, etc). For example, in our work we have found that the spontaneous adoption of the somewhat complex row planting and inter-row cultivation done with animal drawn equipment has been rather low. This is the reason why, in the Central Agricultural Region, we have placed a good deal of emphasis on helping extension/development agency staff to train farmers in row planting. Also, because of the harsh climatic environment of Botswana, there is little flexibility in the farming system. This is because a key management factor is the ability of farmers to plow and plant when it is likely to improve water availability for plant growth, and to improve the efficiency of water use. Therefore, researchers in our situation are faced with the challenge of trying to develop relevant technologies to break a major constraint, rather than the easier task of developing technologies that will avoid the constraint by exploiting the flexibility that exists within the farming system [Norman and Collinson, 1986]. Under these conditions, adoption by farmers of such technologies involves major changes in their farming system. For example, much of the ATIP work has concentrated on the plowing-planting operation. Strategies to improve the amount of water available to the plant at planting time generally require more draft than the traditional strategy of broadcasting the seed and plowing it in. Consequently, it is not surprising that spontaneous adoption of row planting and inter-row cultivation has, in general, been low because aggressive farmer training programs have not been organized[5], and sometimes the necessary external inputs have not been readily available. Interestingly enough, in the case of row planting we have found that wealthier farmers had a much higher level of adoption than poorer farmers [Worman, Williams, Tibone and Heinrich, 1990)[6]. Obviously, the relative risks for wealthier farmers in making major changes in their farming systems was much lower than for poorer farmers

(d). We do not actively promote the adoption of technologies that have been tested in the villages where we work. And, at the same time we do not plan on helping extension/development agency staff actively promote such technologies until the Recommendations Committee has approved them. However, we do see there is a

[5]. In a sense, implementation of such programs would mean that any adoption occurring would cease to be spontaneous. One interesting alternative that ATIP has tried, instead of a massive aggressive farmer training program, is to concentrate on teaching row planting to a few farmers, who have then done row planting on a custom-hire basis for other farmers. Because of the amount of row planting these farmers did in one year, they quickly built up their managerial skills with respect to this practice [Modiakgotla, 1989].

[6]. See also discussion in Section 11.5.3.

role for more widespread testing of technologies, for example, through extension-oriented farmer groups. To help in this, a series of leaflets are being prepared entitled ***Guidelines to Promising Technologies***. These leaflets will provide guidance on specific technologies to extension staff who wish to encourage farmer testing. However, these guidelines do not constitute official recommendations. Although we appreciate that many recommendations are likely to be location-specific, we believe that there should be independent evaluations of the proposed recommendations, taking into account national/societal interests, compatibility with actual and planned support systems, sustainability issues, etc. The forum for approving these recommendations is the Recommendations Committee in DAR.

(e). Our supportive role with respect to helping the extension/development agency staff disseminate technologies outside the ATIP villages, has to date, been largely confined to working with those technologies that are already officially approved recommendations. For example, in the researcher-oriented farmer groups in the ATIP villages, technologies that are not officially recommended, are tested with farmers. In the extension-oriented farmer groups in other villages in the area, where we play a supportive role, usually only recommendations that are officially approved, are offered to farmers. However, as we indicated above, we do see a role, in the future, for more widespread testing of technologies that appear in the series entitled ***Guidelines to Promising Technologies***. Also, we see a continuing role for FSR teams in farmer training courses and agricultural shows in helping extension/development agency staff to train farmers in row planting, which has been officially recommended for many years.

3.4 SUPPORT SYSTEMS AND POLICY LINKAGES

3.4.1 SIGNIFICANCE

As we indicated earlier (Section 1.1.1) an important factor influencing whether the productivity and the welfare of farmers will improve, are the policies which shape the economic environment in which they operate. Policies refer to actions and rules of government implemented in order to meet regional or national development goals [Byerlee et al., 1980: p. 6].

Many policies influence production decisions by farmers. The influence of these may be direct or indirect. For example:

(a). A policy decision to distribute sorghum seed but not cowpea or groundnut seed through the government distribution system influences farmer decisions directly.

(b). Most policies influence farmer behavior indirectly through their effects on input prices (e.g., through subsidies) or product prices (e.g., through marketing boards). Many of the GOB initiatives undertaken through the Arable Lands Development Program (ALDEP) and the Accelerated Rainfed Arable Program (ARAP) have had an indirect impact on farmers' decisions.

Obviously such policies not only influence the farmers, but can also have an impact on what constitutes relevant agricultural research. On-farm research programs can provide information to the policy maker which may be used to create new policies to enable farmers to adopt relevant improved technologies. For example:

(a). On-farm trials may demonstrate the potential pay-off to a particular input which is

not currently available. This information can be fed to the policy makers to convince them to make that input available.

(b). Information obtained from on-farm work with farmers can identify possible discrepancies between stated policy goals and policy implementation -- therefore alerting the policy makers to the changes that are required. For example, ALDEP is distributing a large number of row planters with the stated policy objective to encourage farmers to row plant. However, a survey of row planter usage, which has recently been completed, indicates that many need adjustment and parts replaced. Farmer training programs and ready availability of spare parts and trained artisans are obvious strategies that need to be implemented to ensure that the stated policy goal is fulfilled.

3.4.2 LINKAGE ACTIVITIES

A general principle underlying the development of any linkage arrangement is that there must be perceived benefits to all the parties involved. This is particularly important in the case of links with individuals in planning who do not have day-to-day contacts with FSR teams in the field. Therefore with respect to this linkage, we now make sure that we have the support and interest of the appropriate authorities before undertaking any major independent study geared towards policy issues.

Linkage activities can be considered at two levels. They are:

3.4.2.1 Cooperation With Development Programs In The Region And At The Center

Examples of these include ALDEP, ARAP and non-governmental organizations (NGOs) such as the Tutume Brigade, Palapye Development Trust, etc. These programs participate in activities similar to those undertaken by the formal extension program. An example of an activity which can help such agencies involves the recent row planter condition survey conducted with the support of ALDEP which was referred to above (Section 3.4.1). This survey is likely to result in specific recommendations concerning training courses, adjustment, repairs, stocking of spare parts, etc.

In the future it is likely that linkages with the development agencies will increase. By working with personnel in such programs, we assist in identifying problems that farmers experience which may inhibit their ability to benefit from the support programs. As a result of such collaboration, changes may occur to optimize the benefit to the farmer.

3.4.2.2 Cooperation With Planning At Headquarters

Planning activities within MOA is the responsibility of the Division of Planning and Statistics (DPS). The link to planning is developing slowly. A formalized system already exists, whereby policy issues are channeled to the MOA Policy Committee through the relevant departmental director. However, day-to-day links have tended to be more informal. For example, farming systems personnel have been requested to comment on such matters relating to consultants (i.e., terms of reference, reports produced by consultants), and on proposed developmental initiatives. Additionally, at the request of the Chief Agricultural Economist, farming systems teams have carried out an impact evaluation of the development programs [ATIP, ADNP and FSSR, 1988]. We see FSR team activities continuing to develop informally with DPS, and we also believe it is important to respond to any requests

they make for information and studies. However, it is important to bear in mind that FSR teams work in limited numbers of areas with limited numbers of farmers. Therefore surveys confined to the areas where FSR teams operate should not be mistaken for a nationally representative sample survey. Nevertheless we do believe that information collected by FSR teams can provide data useful to planners.

There are two major reasons why we expect this linkage to continue to grow in significance in Botswana. These are as follows:

(a). It is likely that the limited-resource farmers that FSR teams work with, will continue to be the focus of subsidy programs, i.e, development programs, for many years to come. Therefore issues will continue to arise about the optimal use of subsidies.

(b). It is likely that the adoption of the proposed National Conservation Strategy (NCS) will entail the implementation of strategies designed to ensure sustainability while at the same time encouraging production. What happens now -- as far as the present generation of farmers is concerned -- has a bearing on what is potentially possible in the future. Current adoption of technologies and implementation of support programs can have negative or positive influences on environmental stability. Obviously technologies that are developed by DAR researchers are being screened for their possible environmental impact, for example, on conserving the productivity of the soil.

To ensure future environmental stability, both technologies and policy support systems must be designed and implemented immediately. Additionally, policy/support systems need to reflect the idea that if something is taken out in encouraging production, something else needs to be put in to ensure land productivity in the future. For example, ARAP and ALDEP provide incentives for destumping. This could possibly have a negative impact by encouraging erosion, thus lowering the potential of the land in the future. A constructive policy is to encourage destumping along with a program to promote the planting of windbreaks, living hedges, etc. It is essential to bring about a convergence between the private short-term interests of farmers to maintain an adequate standard of living, and the long-term societal interest in preserving the environment for future generations. The closer the farmers are to the subsistence level, the more concerned they are about survival until next year, and less concerned they are about ensuring environmental stability for future generations. Conservation measures by themselves are unlikely to be very attractive to limited resource farmers as a whole, unless they are implemented with a high degree of subsidization, or by using more of a "carrot and stick" approach -- that is an obligation to put some effort into a specific conservation practice, in order to benefit from programs designed to stimulate production. The latter strategy is probably more realistic under the circumstances in Botswana. Production does not have to be pursued at the expense of conservation as long as the people responsible for developing technologies and policy support programs take conservation into consideration.

3.5 USEFUL REFERENCES

Section 3.1:

Chambers, Pacey and Thrupp, 1989.
Farrington and Martin, 1988.

Section 3.2:

Caldwell and Walecka, 1987: pp. 47-50.

Section 3.3:

CIMMYT, 1984.
Modiakgotla, 1989.
Shaner, Philipp and Schmehl, 1982: pp. 149-159.
Worman, Williams, Tibone, Heinrich, 1990.

Section 3.4:

ATIP, ADNP and FSSR, 1988.
CIMMYT, 1988A: p.3.
Norman, 1989B: pp. 295-296.

PART TWO:

GENERAL IMPLEMENTATION GUIDELINES

CHAPTER 4: DESCRIPTION AND DIAGNOSIS

4.1 PURPOSE AND INFORMATION NEEDS

4.1.1 PURPOSE AND STEPS

The purpose of farming systems research is to help in improving the productivity of farmers in a specific target area. Target areas may be a specific environment (e.g., Molapo areas) or a geographic region (e.g., Ngamiland) or both.

Target areas are usually chosen by government policy makers. Once a target area is defined, and research areas selected within the target area (see Section 2.6), the descriptive and diagnostic activities can begin. The objectives of these descriptive and diagnostic activities are to:

(a). Develop a basic understanding of how the farming system is operating within the target area/group.
(b). Use this information to identify problem areas, or areas of under-utilized potential, that could benefit from change.

To put it more simply, in order to introduce change, it is first necessary to understand what farmers are doing, and why they are doing it in a particular way. Then, in the diagnostic activity, this information can be used to identify areas within the farming system where improvements can be made.

Zandstra [1985: pp. 168-172] gives a description of a nine step design sequence which is based primarily on work at the International Rice Research Institute (IRRI) and the Tropical Agricultural Research and Training Center (CATIE). This descriptive/design phase involves two related activities: to design improved production systems, and the formulation of an overall research program[1]. The steps are as follows:

(a). ***Analysis Of The Region And The Target Production Systems.*** Once the target area has been selected, the design methodology begins with an analysis of historic events, migration flows, customs of ethnic groups, population growth rates, and development trends which must be analyzed to be able to arrive at an understanding of the factors that might stimulate or impede activities required for the improvement of the production systems.

(b). ***Definition Of Development Objectives In The Region.*** One basic consideration is to determine how important the production system under study is in the region, e.g., how important is a sorghum-millet-cowpea food crop system with animal traction in the region? Secondly, it is important to consider the reasons behind the particular form of the existing production system. Too often the diagnostic phase provides information on the systems' form, without an understanding of why farmers do or do not utilize particular technologies, for example, why don't farmers use row planting,

[1]. Some of the latter (i.e., steps (d) or (e) to (i)) are really design-related activities and therefore are not discussed in this chapter. Design and testing activities are considered in Chapter 5.

or produce fodder crops when these practices have been extensively promoted?

Zandstra [1985, p. 169] emphasizes the importance of this step with the following statement:

> "In this descriptive analysis of the system, it is important to take into account the human component, and the objectives, plans and attitudes of the farm family and the institutional structure within which they operate. The design of alternative production systems begins to take form once the development objectives of the study region are understood. These objectives exist at three levels:
>
> i. Objectives of the government and of the national research institution.
> ii. Objectives of the group of researchers responsible for the design and transfer of alternative production systems.
> iii. Most importantly, the objectives and goals of the producer."

(c). ***Analysis Of The Production System Or Sub-system To Be Modified.***[2] In this step there are generally three levels of analysis:

i. The first level of analysis is to consider outside or exogenous factors that have an impact on the system. These often explain certain characteristics in the system, such as disease occurrence, genetic potential of livestock, etc.

ii. The second level of analysis is structural and refers to an inventory of land uses, structures and equipment.

iii. The third level of analysis focuses on the way the system functions and thus addresses the management of the production system and the interaction of the production system under consideration with other systems on- and off-farm. It is at this point that constraints to production, and flexibility in the farming system, are determined. Critically important in this exercise is to obtain the opinions of farmers themselves as to their problems. Farmers in fact are often able to pinpoint problems that would take researchers a long time to discover. Simple qualitative modeling of the system, discussed shortly (Section 4.2.1), is also a potentially useful approach to help structure understanding of researchers at this point.

Just to identify the problems, or areas of potential improvement, is not sufficient. For example, it may be noticed that farmers do not plant in a timely manner, even though planting opportunities are scarce. It is not enough just to go to the farmers and tell them to plant in a more timely manner. It is first necessary to understand why they are not doing so. It may be due to the fact that most of the farmers are sharing draft power so that they work first on one field, then on the next. Or it may be that farmers do not have enough labor to look after the cattle, and kraal them every night;

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[2]. A list of the type of data that is useful to have available for the descriptive process, is similar to that was earlier indicated as being useful for research area selection (Table 2.3).

so they let them wander in the bush. Consequently, when it rains the farmers have to go and look for them. So to help farmers solve the problem of delayed planting, a researcher would need to have a clear understanding of the source of the problem.

Thus, the information sought during the diagnostic activity usually involves collecting more detailed information on specific questions that come out of the descriptive activity. This information most commonly needs to be collected in the field. While examining problem areas in detail in the field, researchers should also try to assess how widespread and severe particular problems are among the target group. Questions like; how often the problem occurs over years, how many farmers it affects, does it have a severe impact on production and incomes etc., need to be answered. This type of information is necessary for deciding what problems or opportunities are most important, and for setting the priorities of the research program. A more detailed discussion on this important point is presented below (see Section 4.1.4).

(d). ***Definition Of Recommendation Domains.*** At this stage the team is interested in identifying a maximum percentage of the potential target population in a minimum number of stratifications. The stratification of domains usually starts with ecological factors such as climate and may include farm size, distance to markets, control of traction, etc.[3]

(e). ***Identification Of Technical Interventions.*** The research team should now be able to identify a number of practices or technologies which have the potential to increase productivity. Possible sources for these are mainly from on-station research work, RMRI work on farmers' farms, and from other farmers. The solutions identified should be closely related to the production constraints previously identified.

(f). ***Ex ante Analysis Of Potential Alternatives.*** The design alternatives can be specified as a set of proposed changes in the existing production system. The **ex ante** analysis seeks to evaluate the expected biological and economic impact of making these changes. The difficulty and risk associated with crop and livestock systems makes this step of predicting the outcome of a change particularly important in order to reduce the chance of adverse effects on the farmers. The analysis will require information on resources and their costs. A partial budget can be constructed for each alternative to predict its economic viability. In addition, the impact of the proposed changes on the whole farm, particularly in terms of changes in farm labor demand, cash inputs or specialized equipment, must be evaluated.

(g). ***Evaluation Of An Alternative Production System.*** The outcomes of the **ex ante** analysis can be compared to similar types of information about the existing systems, and with other potential production systems to determine the acceptable range of production outcomes, and to see if the proposed changes are feasible. In addition, changes in the levels of inputs and management components need to be evaluated.

(h). ***Listing Of Assumptions And Requirements For The Alternative Production System.*** Once a system has been selected for field evaluation, it must be described in detail, specifying inputs required and assumptions concerning levels of management,

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[3]. More information on recommendation domains -- which Zandstra [1985] calls adoption domains -- is given in Section 2.3.

institutional support, etc.

(i). ***Identification Of Research Priorities.*** Information gaps which have been encountered in the design process, such as unspecified biological relationships, prediction of the performance of alternative management practices, or questions of farmer attitudes, should be listed. These then become the basis for a set of research priorities, and trials can be designed on-station and, if necessary on-farm, to provide the needed information.

4.1.2 DEGREE OF UNDERSTANDING REQUIRED

The steps described in the previous section appear to have the potential for being very time consuming. This is likely to be the case if an effort is made to collect at first hand large amounts of accurate quantitative-type data. However, is this always necessary or even desirable? The answer of course is no! Collecting descriptive information is not an end in itself but is used to provide an input into designing and testing work.

In Botswana we suggest that the following guidelines should be used:

(a). Make as much use as possible of existing secondary information (see Section 4.1.3).

(b). Very carefully consider just how accurate descriptive information needs to be in order to provide an adequate guide or input into the designing and testing stages of FSR. Whenever possible, emphasis should be placed on collecting the required information in the cheapest possible way, with a method that allows attainment of the degree of accuracy that is required (see Section 2.5.1). Examples of cheap methods are those that emphasize qualitative rather than quantitative type of data, and relative ranking of data rather than actual accurate measurement.

(c). Mainly use informal interdisciplinary surveys to collect information required to fulfill (b) above that cannot be collected under (a) above. The major respondents for this information should be the farmers' themselves (see Section 7.2.4). If necessary these findings should be supplemented or confirmed with a formal one-time survey that can be analyzed quickly.

(d). Bearing in mind (a) to (c) above, reduce to a minimum the amount of time taken in doing the initial descriptive/diagnostic work, in order that design and testing activities can start at the earliest possible opportunity.

(e). Descriptive/diagnostic activities to verify the initial quick descriptive/diagnostic work can, if necessary, be undertaken at the same time as the initial testing stage work is being undertaken. These descriptive/diagnostic activities could be in the form of more formal surveys[4], and studies such as monitoring fields, etc. In fact, results arising out of design and testing activities can help in refining future descriptive/diagnostic activities. This is an example of the iterative nature of FSR work.

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[4]. For example, the multiple visit surveys we did at the beginning of ATIP were undertaken at the same time as the first year's testing work. However, as is discussed later in the handbook, we now believe that the costs in time and resources involved in collecting and analyzing the data, in relation to the expected returns, probably did not justify them being used on a regular basis (see Section 7.3.1).

4.1.3 USING EXISTING INFORMATION

As was indicated above, during the descriptive work, researchers need to collect information on a wide range of subjects. Much of this required information will be available in government reports and other published materials. For example, the number of households in a particular village may be listed in the government census report. Information on rainfall and temperature, for particular areas, is usually available from reports published by the Meteorology Department, etc. These sources of information are called secondary sources, meaning that the information was collected by someone else. In addition to being a cheap way of obtaining information, it allows the researcher to learn from what has been done previously and allows the researcher to avoid repeating what others have already done.

When using secondary sources of information, it is also important to carefully assess the way the information was collected, to determine how reliable it is, and to determine whether it is relevant to the target area/group. For example, census data on the number of households in a village that was collected in 1970, may not be a reliable estimate in 1990. Estimates of crop yields in 1987-88 that were collected in 1990 by asking farmers to try and remember what they harvested, may also be somewhat unreliable. And monthly rainfall data for one location, in one year, may be irrelevant when trying to obtain an estimate of the long-term average annual rainfall for a region.

Thus, while it is critical for researchers to utilize the existing information, great care must be exercised to see that the information is used correctly. Field research should only be used to verify or to fill in the gaps in the existing information.

Some useful sources of existing information are given in Table 4.1.

TABLE 4.1: EXAMPLES OF SOURCES OF EXISTING INFORMATION IN BOTSWANA

TYPE OF INFORMATION	SOURCES
Rainfall and Temperature:	Monthly Weather Bulletins (Meteorological Services, Ministry of Works and Communication)
Soils, Topography, Land use:	Soil and Topographical Maps (FAO Soil Mapping Unit, Ministry of Agriculture), Aerial Photographs and Maps (Department of Surveys and Lands, Ministry of Local Government and Lands), Land Use Studies (National Institute of Research, University of Botswana)
Population Statistics:	Census Reports (Central Statistics Office, Ministry of Finance and Development Planning)
Sociological Information:	Reports (Rural Sociology Unit, DPS, MOA), Reports (Rural Development Unit, Ministry of Finance and Development Planning)
Farm Statistics:	Farm Management Reports (DPS, MOA), Agricultural Statistics (Agricultural Statistics Unit, DPS, MOA)
Agricultural Technology Options	Research Reports and Papers (DAR, MOA), Agrifacts (DAES, MOA)
Policies and Support Systems	Reports (DPS, MOA), Monitoring and Evaluation Reports (ALDEP)

4.1.4 SETTING PRIORITIES

During the descriptive and diagnostic work, it is likely that researchers will observe more problems in the farming system than they can possibly hope to address. Researchers' time

and resources are often limited, so they must carefully consider how much work can be done, and restrict the number of activities taken on. Trying to do too much generally results in the work being done poorly. At the same time, researchers must be sure to address the more important topics in their research area, so progress can be made. For this reason, it is necessary for researchers to set priorities on different topics in order to help them choose which topics to work on. Four factors that are important in influencing the setting of the research priorities are as follows[5]:

(a). Farmers' objectives have a direct effect on the types of technology that they will adopt. If researchers and farmers have different objectives, a good deal of research work may end up being wasted. For example, there was one case in Botswana, where researchers worked closely with farmers to develop a very productive cropping system. When farmers used the system, in a year of good rainfall, they produced two to three times more than their food requirements for that year. Researchers were very happy and expected farmers to continue using the system. However, the following year many of the farmers decided not to plant at all! The researchers' objective was to get farmers to produce more food for the nation, while the farmers' objective was just to produce enough food for themselves. Consequently, the researchers had to start again; this time from the farmers' perspective. Thus, it is important that researchers understand farmers' objectives before they begin large research projects. This should be determined during the descriptive and diagnostic stage. In addition, it is necessary to identify which problems the farmers in the target area consider most important. Farmers will be most enthusiastic about research that addresses issues they consider important. However, it should also be noted that they may not always identify all the major problems.

(b). Another client for FSR teams are station-based researchers who play a major role in providing a 'bank' of potentially useful technologies that can be considered in the design stage and used in the testing stage. Although the farmer remains the major client for FSR work, FSR teams can help in developing a more useful "bank" of technologies by responding to on-station researcher requests to test specific potential technologies on farmers' fields.

(c). To benefit from the interdisciplinary nature of FSR, research priorities must be set by the whole team, and not just by discipline. For example, if descriptive and diagnostic activities indicate that labor is the most limiting factor in the system, then the agronomist should give priority to this and work with the economist to develop labor saving technologies, rather than addressing some other topic that may be only an agronomic issue, such as sorghum variety yield trials.

(d). The mandate and the location of the research will have an influence on setting research priorities. For example, a team may be responsible for increasing crop production among limited-resource farmers working on the molapo, around Gomare. Thus, the team usually starts out with some specified objectives and target areas.

Some other issues to consider when setting priorities for research include the following:

(a). How common is the problem within the research area, and how many families does it affect? Higher priority should be given to problems that affect most families.

(b). How severe is the problem, and how much does it affect the productivity of the

[5]. They are not listed in any particular order of priority.

system? For example, head smut in sorghum may occur in all fields throughout a region, but the actual reduction in grain yield may be very small. Higher priority should be given to problems that have the most severe effects on farm production.

(c). What is the potential for solving the problem? It may not be appropriate for an on-farm research team to tackle a problem like bird control, even though all parties recognize it as a problem. On-farm research teams should generally give priority to problems they feel they have some chance of solving, and try to feed back problems they can't solve to other groups which have a better chance of identifying a solution (e.g., station-based researchers).

(d). Are there areas of opportunity for increasing farm production which are being under-utilized at present? For example, could certain types of fruit trees, planted around the home compound, provide useful income? Not all improvements come from solving problems. Some may come from starting new and profitable activities.

4.2 OBTAINING INFORMATION

4.2.1 MODELING

A model is a means of describing and summarizing a system and its known properties. It helps researchers understand what they are studying and where there are gaps in their knowledge.

4.2.1.1 Types Of Models[6]

There are two basic types of models: quantitative and qualitative. A very simple quantitative model is as follows:

$$Y = 5X$$

where Y = kilograms of sorghum and X = kilograms of nitrogen. This model describes the response of sorghum production to nitrogen inputs. It says that adding one kilogram of nitrogen increases sorghum production by 5 kilograms.

In FSR the objective is to describe, in a holistic manner, not only the farm production system but also human behavior, in order to develop an understanding of how farmers manage their farms. Modeling human behavior is obviously much more complex than modeling fertilizer response and some other aspects of production. Qualitative models can be used to describe the farming system and to improve our understanding of important linkages, constraints and interactions. These models are often presented diagrammatically and aim to convey the information in a manner that is easily understood.

Within the qualitative models category, the structural model is particularly useful in farming systems work, and will be discussed here. Quantitative models may be useful in more advanced farming systems work, and will also be briefly discussed.

[6]. Much of the material relating to structural models was excerpted from Frankenberger and Waleeka [1987: pp. 43-50]

4.2.1.2 The Structural Model

A structural model of a farming system is a diagram representing the principal resources, enterprises and outputs of an individual farm household and the interaction among all these different elements. A general model of a farming system was presented earlier in the handbook (Figure 1.2). This model diagrammatically represents the interactions of the elements, factors, inputs and processes which together make up a farming system.

The structural model often represents a first step in describing a farming system, and is by no means exhaustive. It may be important for orienting and guiding the work of an interdisciplinary team. Understanding the whole context within which new technologies are to be promoted will help the team evaluate the potential of a proposed technology. Modeling also helps to identify features at the farm level which may need to be examined in greater detail. It is at this level that trade-offs and conflicts can be identified.

Information for constructing a structural model is usually obtained from secondary sources, rapid reconnaissance surveys, and informal surveys with key informants. Modifications to the model may be based on multi-visit surveys, single purpose surveys and researcher experience with the system. Versions of a systems model which are revised on the basis of additional research data may focus on a farm household's management strategies. This type of model is sometimes called a process model and is used to develop an understanding of the way farmers go about managing their farms.

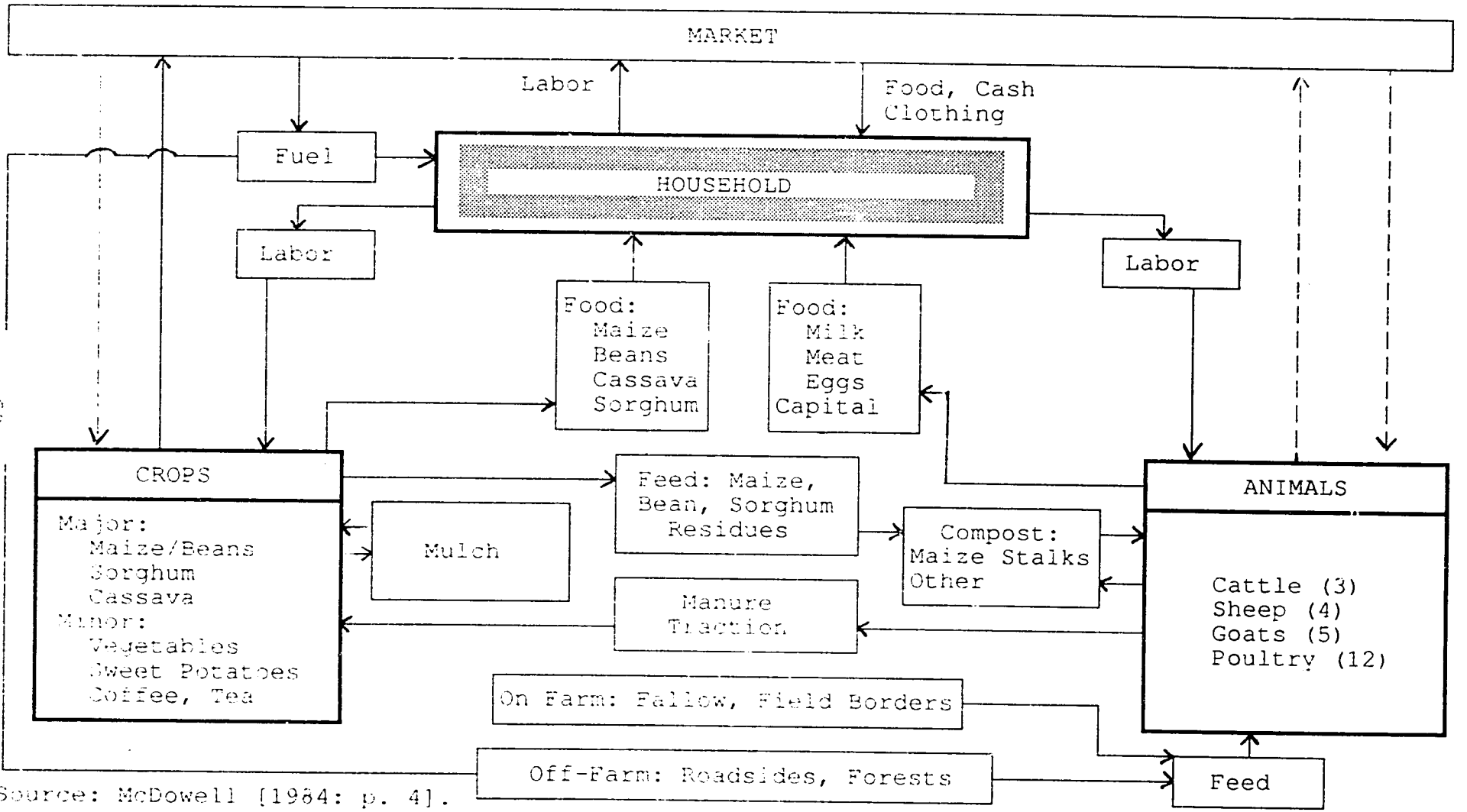
A different representation of information on the farm household and its crops and livestock is presented in Figure 4.1 and is particularly useful in examining relationships between crops and animals. The following discussion of this model is taken from McDowell [1984: pp. 1-3].

> "The box identified as "market" in Figure 4.1, represents all off-farm activities and resources; thus, it includes products sold or labor going off the farm as well as purchased inputs and household items. The "household" is the core of the farm unit.
>
> In preparing the model of a typical system, labor use, sources of human food, household income, animal feed, and the roles of animals are the main focus. The solid arrows (——>) portray strong flows or linkages (e.g., more than 20% of the total income arises from the sale of crops, animals or household-processed products). Broken arrows (----->) are used when sales of crops or animals contribute less than 20% of household income, the interchange among functions is intermittent, or there is as yet no routine pattern identifiable. Family labor applied to crops or animals is identified but off-farm employment or the use of hired labor is not quantified except generally and is indicated by broken or solid arrows.
>
> Fuel is incorporated in the model because the gathering constitutes a significant expenditure of labor and may influence the labor allocated to animals more than to crops."

4.2.1.3 Biological And Socio-Economic Models

These models are usually quantitative in nature and include biological simulations (e.g., crop growth models), economic decision models (e.g., linear programing models), and bio-economic models which may either be descriptive or quantitative in nature. Numerous

FIGURE 4.1: MODEL OF TYPICAL LOW RESOURCE FARMS IN WESTERN KENYAN HIGHLANDS WITH CROP AND ANIMAL SUB-SYSTEMS



Source: McDowell [1984: p. 4].

File: A105.1/4T.HP

Date: April 6, 1990

publications discuss these types of models[7]. Generally they require extensive staff resources and sophisticated computer facilities to develop. Once developed, they may be useful in examining proposed changes in the total farming system, or some sub-system.

4.2.2 APPROACHES IN CROPPING SYSTEMS DESCRIPTION/DIAGNOSIS

Cropping systems research is a part of FSR. Within FSR, it is usually the responsibility of the agronomists to develop a clear description of the cropping systems being used in the target area. To do this the agronomist must work closely with farmers and research scientists in other disciplines. The description must be both clear and sufficiently accurate to form the basis for future research programs.

4.2.2.1 Descriptive Activities

We have used three main approaches for descriptive work in cropping systems research in Botswana. These are as follows:

(a). ***Secondary Information***. Secondary information (e.g., national census and agricultural statistics material) is an extremely important resource in cropping systems research.

(b). ***Surveys***. Informal and formal surveys -- where researchers meet with farmers and discuss the types of cropping systems they use -- are tools used to verify the accuracy of secondary information, to fill in gaps in the knowledge available from secondary sources, and to gather more detailed information about local cropping systems. In designing and conducting these surveys, it is important that agronomists work together with researchers from other disciplines. For example, socio-economists will help agronomists to ensure that they are interviewing a representative group of farmers, so that the findings are not biased by interviewing an unusual set of farmers. Also, economists and other social scientists usually have more training and experience in designing and conducting surveys than do agronomists. Thus they can often help the agronomist to design more efficient and meaningful surveys. Furthermore, problems in cropping systems activities often cross discipline boundaries. For example, it may turn out that the farmers' biggest cropping problem is in finding the labor to do the work. This is a socio-economic problem, not a biological one.

As was indicated earlier (Section 4.1.2), emphasis initially should be given to informal surveys and supplemented later, only if necessary, by more formal surveys. In cropping system descriptive surveys, researchers usually ask farmers for detailed information on such items as what farmers plant; when and how they plant; why they have chosen a particular planting method; the type of draft power they use and where they get it from; their systems for managing soil fertility, weed and pest control, crop harvesting, threshing and grain storage systems, etc. It is also important to establish who actually does the work (e.g., do men always do the plowing, do women do all of the weeding, etc.) because it affects what type of changes can or should be introduced. Another important area of descriptive work in cropping systems is to get the farmers themselves to clearly identify what they consider to be their major problems and limitations to crop production.

[7]. For example, see Anderson, Dillon and Hardaker [1986], Gutierrez-Aleman, Boer and Hart [1986], and Dillon and Hardaker [1980].

(c). ***Monitoring Studies.*** Monitoring farmers' activities in the field is another useful tool in farming systems descriptive research, although because of the time this takes, it is usually done at the same time as initial design and testing work is undertaken (see Section 4.1.2). Findings from monitoring activities, and initial testing work can then help refine decision making with respect to design and testing activities in the future. Monitoring activities can be important because farmers sometimes cannot give the researcher a very precise description of their cropping system. For example probably cannot tell the researcher exactly what fraction of a hectare they can plow with their team of oxen in a morning, and they will not be able to say precisely what stand densities they hope to achieve in their fields. Researchers will greatly strengthen their own understanding of local cropping systems, and be able to better quantify specific aspects of the local systems, by monitoring some of the farmers activities in the field. This requires actually going to the field and measuring specific items such as the rate of plowing by oxen and donkey teams -- area plowed per hour -- plant stand densities actually achieved, the amount of area devoted to certain crops and/or crop mixes, the amount of labor required to plow a hectare, or weed a hectare, the typical yield levels of different crops in different years, etc. This information can also be used to check the accuracy of the data obtained from on-farm surveys and secondary sources.

During the descriptive activities it is critically important to find out precisely why farmers use specific cropping systems and what they hope to achieve through their cropping activities (e.g., are their cropping activities their main source of food and income, or do the farmers have other sources of income, like large cattle herds?). The answers to these questions will have a major effect on the type of changes the researchers will want to test.

4.2.2.2 Diagnostic Activities

Information from the descriptive activities, which emphasizes farmer input, is used by researchers to develop hypotheses about problem areas within local cropping systems, and to identify areas of possible improvement. The purpose of the diagnostic activities is to verify that the problem identification is correct, to more clearly define certain identified problems, and to collect information on the magnitude or size of identified problems. For example, suppose that in descriptive work many farmers stated that aphids were a problem in sorghum production. Researchers might then form the hypothesis that controlling aphids could help increase sorghum yields in the region. Diagnostic activities would then be used to determine precisely how often aphid infestations occurred on the sorghum crops, how much of the fields the aphids covered, and by how much the aphids were reducing per hectare grain yields. If it were discovered that aphids occurred in most sorghum crops, but only affected small portions of each field and only reduced grain yields by an average of, say, four percent, then aphid control in sorghum would probably not become a high priority research subject. On the other hand, if it were discovered that aphids occurred in 90 percent of all sorghum crops, that they generally covered the whole field, and that they reduced grain yields by 50 percent or more, then controlling aphids might really help to increase sorghum yields. Researchers might then decide to devote a lot of effort to the problem.

There are many possible approaches that can be used in diagnostic work. The decision as to which are the most appropriate ones will depend on what information is required, what resources are available to the researcher, and the local situation. Bear in mind that diagnostic activities, which in a sense are more tightly defining problem areas, can continue while testing work is going on in other subject areas Some of the approaches which have been successfully used in Botswana for diagnostic studies in cropping systems research are

as follows:

(a). ***Special Subject Surveys.*** One of the most common techniques is special subject surveys. These are surveys conducted with the relevant farmers, aimed at obtaining detailed information on specific subjects. For example, researchers may have noticed that many farmers own planting and weeding equipment, but do not appear to use it. A special survey could then be administered to those types of farmers, and the survey might deal only with that subject. It might include questions such as when, where and why the farmers purchased the equipment, why they were not using the equipment, were they ever given training in the use of the equipment, are spare parts available, etc. This type of survey may be either an informal or formal survey. The number and type of farmers it is administered to would depend entirely on the subject of the survey.

(b). ***Monitoring Studies.*** Another common and important approach in cropping systems research is direct field measurement. This is often necessary when farmers can identify a general problem, but cannot be sufficiently specific for researchers to know how to address it. For example, farmers may list poor soil fertility as a problem, but researchers will not know exactly which soil nutrients are low, or why, until some soil analyses are performed. The same might apply to the question of stand establishment. Farmers may complain that they often have poor crop stands, and may often blame this on the sun. However, there are many possible reasons for poor stand establishment including the use of poor quality seed; plowing the seed too deep for it to emerge; applying too little seed; seed being destroyed in the soil by insects or other soil organisms; planting on marginal soil moisture; soil crusting; or indeed, high soil temperatures. Before researchers can start to address the problem, they will need to identify the major causes. If no studies have been previously conducted, diagnosing the source of the problem will require direct measurement of the relevant parameters in the farmers' fields. This type of study often requires the assistance of on-station research specialists (e.g., soil scientists, entomologists, plant breeders, etc.) and provides an ideal opportunity to develop the linkage between on-station and on-farm research.

(c). ***Field Trials.*** A third type of diagnostic tool is the diagnostic field trial. Suppose, for example that farmers list "weeds" as one of the major factors limiting crop yields. It would probably be a good idea to determine what types of weeds they are referring to, and to work with scientists from other disciplines to determine whether the "weeds" themselves are a problem because they are hard to remove, or whether the real problem is in obtaining labor to remove the weeds. These questions could be addressed through surveys and field measurements as described above. However, it might also be informative to conduct field trials to determine exactly how much the "weeds" really do reduce crop yields. To conduct such a trial, the researcher selects fields which are representative of the target area. Then after the farmers plant, researchers mark out pairs of field plots. One plot is kept weed-free -- either by hand labor or chemicals -- while the other plot is subjected to the farmer's normal weed management program, and plot grain yields are measured at harvest. So long as the trials are conducted on enough representative fields, and over a range of different environments -- good environments to poor environments -- the researchers can develop a good estimate of how much reduction in grain yield is due to "weeds". In designing this type of trial, it may be helpful for the researcher to consult the biometric staff at DAR.

Another variation of the diagnostic trial can be used when researchers are trying to determine which components of a possible package of improved practices are most

important. While researchers may be able to think of many improved practices for farmers to adopt, farmers themselves will normally adopt only one or a few new practices at a time. Thus it is important for researchers, extension agents and farmers to know which areas to work on first. For example, after the descriptive studies, it may be clear that water conservation strategies, soil fertility, row planting, improved weed control and pest control would all help to increase crop production in the target area. But which ones would be most beneficial? One way to answer that question is through a trial, or series of trials. Treatments in these trials could include single treatment comparisons, such as water conservation plus the farmer's traditional management system (TS), fertilizer plus TS, row planting plus TS, etc. Or the researcher may want to compare pairs of options, such as water conservation plus fertilizer plus TS, versus water conservation plus row planting plus TS, versus row planting plus fertilizer plus TS, etc. These may also be compared against a system that includes all of the possible options, to estimate how far they fall short of the effect of applying the complete package. This type of trial has sometimes been referred to as a Steps in Technology Trial (see ATIP [1984 and 1985]), and is usually conducted either as an RMRI or RMFI trial[8]. The statistical design and analysis procedures for this type of trial can be somewhat complex. It is a good idea to consult the biometric staff in DAR before implementing this type of trial, to ensure that the trial will answer the most important questions.

4.2.2.3 Conclusion

While conducting research on cropping systems, it is essential that scientists keep in mind the fact that these systems are complex. Cropping activities require labor by the farmers, and often specific tasks are traditionally the work of men, or only the work of women and children. The use and management of draft animals may also be necessary, and the systems must be economically profitable if they are to be used at all. Thus scientists must be aware of the whole picture, and work closely with associates from other relevant disciplines -- both on-station and on-farm -- to ensure that the outcome of descriptive/diagnostic activities is both useful and practical.

4.2.3 APPROACHES TO LIVESTOCK SYSTEMS DESCRIPTION/DIAGNOSIS

4.2.3.1 Using A Systems Approach To Describe Livestock Production

Livestock production plays a significant role in agricultural development and in people's lives. Some of the ways in which livestock production contributes to the lives of people are described in Table 4.2.

In Botswana, most farms consist of two major sub-systems, crops and animals. Small scale limited resource farming is a complex operation involving a large number of inter-related activities. Generally farmers do not make decisions on any farming activity without considering the impact of those decisions on other farming activities. Because livestock production takes place over a much longer period of time than does crop production, the decisions involving this type of production may be more complex and far reaching than decisions involving cropping. Thus, in describing the livestock system and in diagnosing problems within the system, it is important to consider the interactions with other aspects of

[8]. The distinction between diagnostic and design-type trials sometimes become somewhat blurred. The Steps in Technology Trial could also be considered a design-type trial.

the farming system.

TABLE 4.2: LIVESTOCK CONTRIBUTIONS TO PEOPLE

Food:	Meat, milk, eggs
Fiber and skins:	Wool, hair, hides, feathers, and pelts
Traction:	Power for crop production, irrigation pumping, threshing, and transport
Animal wastes:	Fertilizer, heating fuel, methane gas production, feed, construction material
Storage:	Storage of food supply or capital and seasonal excess of feeds
Weed control:	Biological control of brush, plants, and weeds along road sides and waterways
Cultural:	Security and self-esteem -- revered symbols
Sports/recreation:	Competition, exhibition, hunting, and companion animals

Source: Amir and Knihcer [1989: p. 11].

A good place to start the description/diagnosis of a livestock system is to describe the basic components of the entire farm operation, and to establish the linkages and interactions between the crop and livestock sub-systems. Rapid reconnaissance surveys or surveys using recall data can be quite useful in making a general characterization of the farm operation, including an overall view of the livestock operation. General information collected through reconnaissance visits or by questionnaires can be summarized in a model, such as depicted in Figure 4.1. This type of structural model can be used to visualize the relationships between within-farm operations and between the farm and its environment [McDowell, 1984: p.1].

Once the descriptive model has been constructed so that all elements thought to have a significant impact on decision making are incorporated, the boundaries of the animal sub-system can be more clearly defined. Taking into account the interactions identified in the model, specific areas in the livestock sub-system can be chosen for further descriptive/diagnostic study. Important characteristics of most livestock sub-systems which may need to be studied include; seasonal variation in feed resources, availability of labor to the livestock sector, seasonal variations in draft animal needs, and seasonal mortality of young animals [McDowell, 1984: p.2]. The FS team will also wish to examine management level and ability and to determine traditional marketing patterns. The level of veterinary services available and the identification of major disease complexes may also be of interest.

The data needed to evaluate the importance of the major constraints to livestock production may be broadly classified as ecological, biological and socio-economic (Bernsten, Fitzhugh and Knipscheer, 1984: p. 95]:

(a). ***Ecological.*** Land and climate determine the types of plants that can be grown, while the types of plants generally determine the kinds of animals which can be produced in a given ecosystem.

(b). ***Biological.*** These constraints may be sub-classified as nutritional (associated with the quantity and quality of the feed supply), health factors including parasites, disease and predators, and livestock breeds.

(c). ***Socio-Economic.*** These constraints act to limit biological productivity and include factors such as management, input/output prices, input availability, marketing, attitudes towards risk, policies, cultural preferences, and labor availability.

An ATIP paper [Gray, 1986] contains a set of questions used to develop an informal cattle post survey. These questions covered the areas of traction management, herd management (breeding, reproduction and calving, nutrition and grazing management, animal health and

disease control), access to water, labor, cattle ownership, movement of cattle between lands and cattle post area, seasonality, farmer strata, disposition of animals and animal products, and income flows among crops, livestock and other household activities. The information obtained by asking these types of questions can be used to create a model, identifying specific constraints for further study, or indicating which areas should be further monitored to develop descriptive/diagnostic information over a period of time.

4.2.3.2 Monitoring Livestock Production

After a general description of the livestock production sub-system has been obtained, it is usually necessary to monitor some parts of the system over time to identify, or to better define, problems. Several approaches can be taken in the monitoring of livestock production including: periodic inventories; monitoring herd dynamics through rates of production, offtake, and death losses; and special studies to identify specific management or health problems.

Periodic inventories may be undertaken to identify trends in the livestock sub-system of the farm[9]. Data on increases or decreases in livestock can suggest possible areas for study. This kind of inventory is often used in generating national statistics and is collected on a once-a-year basis. It can also be collected quarterly, monthly, or weekly if done in conjunction with other data collection.

We may also collect data on specific changes in animal populations which are reflected in the gross inventory figure. Data collected on a relatively frequent basis (monthly or weekly) on the number of births, number of animals sold, and the number of animals which have been lost or have died will provide data to calculate biological measures of herd performance such as reproduction rates, offtake rates, and death losses. If herds are tagged for identification, more specific monitoring, over a period, can be undertaken which may include weighing (particularly of growing animals) to determine growth rates, and studying their health status.

Specific types of studies to identify health-related or nutritional problems can be undertaken. Studies that ATIP has undertaken include monitoring of various nutrients through blood studies (done in conjunction with mineral feeding), studies of kid mortality (related to management practices), and parasite studies (to determine at what time of the year parasites may be important). These types of studies may be diagnostic in nature, or may involve monitoring interventions being tested.

4.2.3.3 Measuring Benefits From Livestock Production

Benefits from livestock production come in many forms: meat, milk, hides, work animals, eggs, etc. Depending on what the information is to be used for, several ways of measuring benefits are available. Livestock production can be measured in physical units (i.e., in terms of increases in weight per animal, or increases in weight per land area). An economic value of production can be computed which is useful in examining relationships between farm sectors (i.e., crops and livestock), or in comparing benefits from two different types of livestock.

Because much of the value of livestock is derived from products or activities not sold on the

[9]. See Annex Volume for examples of livestock data collection forms.

open market, there is no price readily available for valuing the particular livestock product. With much of the livestock benefit gained in the subsistence sector of the farm, "the results of any calculation of economic costs and returns will be highly sensitive to any changes in the way subsistence production is valued" [Behnke, 1984, p.572]. Generally, it is possible to use a market price for products which are regularly sold. However, production for home consumption is more difficult to value, and must generally be valued at the retail price for a replacement product (i.e., a product which would need to be purchased if it were not produced on the farm) [Behnke, 1984: p.574].

4.2.3.4 Livestock/Crop System Interaction

General livestock/crop system interaction can be identified through the use of the modeling procedure described in Section 4.2.1. More detailed description/diagnosis of this interaction depends on the system being examined. There may be areas of positive interaction (e.g., cattle used for plowing, stover used for animal feed, etc.), and there may be negative interactions (e.g., lack of labor for cropping because of a need to herd animals, animal destruction of crops, etc.). In many cases we have relied on the case study approach to describe the interactions between livestock and cropping systems.

When attempting to measure the benefits and costs of this interaction in economic terms, it is important to remember that [Behnke, 1984: p. 577]:

> "In mixed farming-livestock systems many products generated by a family's livestock enterprise are neither consumed nor sold but rather are invested in the household's cropping enterprise, while the reverse holds true for the cropping enterprise vis-a-vis the herd. Crops or crop residues are used for animal fodder, manure used for fertilizer, or animal traction used for plowing are common examples of such intermediate agricultural products whose value is only realized after the addition of other inputs or processes. The appropriate value of a subsistence input is the cash cost of purchasing its replacement, i.e., the cash cost of buying fodder to replace crop residues, of purchasing fertilizer to replace manure, or of purchasing plowing services in lieu of using the family animals."

4.2.4 APPROACHES TO FARM HOUSEHOLD DESCRIPTION/DIAGNOSIS

4.2.4.1 Introduction

Farm household diagnosis is normally performed in association with cropping and livestock systems diagnoses, not in isolation from them. The diagnosis considers micro (on-farm) and macro (off-farm) conditions influencing the typical farming system, thereby helping to provide data useful in setting a research agenda for future seasons. The diagnosis should begin by describing current farm systems, and how they have changed relative to past systems. The variability in current farm systems will subsequently aid in establishing appropriate recommendation domains.

The farm household diagnosis concentrates on identifying primary constraints encountered in the typical farm system. Obtaining information about these constraints becomes the focus of the present and future seasons' surveys. As information is obtained through the surveys, appropriate unit(s) of analyses are identified. A unit of analysis is usually considered the "farm family", but depending on the cultural situation and/or the particular study being undertaken, it may be more appropriate to study an extended family grouping or individual

family members as the unit of analysis.[10]

The underlying goal of farm household diagnosis is to set guidelines for the farming systems team to follow when collecting data for economic analysis during the implementation of studies, surveys, and trials. A well-focused farm household diagnosis can guide the economist when deciding on the appropriate types of analysis to be used.

This section identifies various factors the farming systems economist may consider in order to obtain crucial information on the limited-resource farmers' primary constraints. Constraints facing the farm household are divided between socio-economic and institutional. One additional important area of farm household research involves food consumption research, which is covered separately at the end of this section.

4.2.4.2 Identifying Primary Socio-Economic Constraints Facing The Typical Farm Household

Previous research in Botswana has identified the following socio-economic conditions and constraints as being of primary research concern:

(a). Defining the types of households, describing the characteristics of the head of household, and the relationships which exists within and between households. These can be used in determining the appropriate unit of analysis.
(b). Household size and labor availability (both household or non-household).
(c). Customary household crops planted and management practices.
(d). Division of household labor among crop and livestock enterprises.
(e). Cattle and smallstock wealth of the household.
(f). Draft type and access.
(g). Sources of on- and off-farm income, and monthly income flows.
(h). Capital resources owned by the household.
(i). Household participation in government programs.
(j). Adoption of new technologies and farmer objectives for the future.
(k). Farmer decision making.
(l). Food consumption patterns.
(m). Marketing patterns.
(n). Census baseline of each research village.

4.2.4.3 Identifying Primary Institutional Constraints Facing The Typical Farm Household

Primary influences and constraints facing the farm household from an institutional perspective include:

(a). Informal and formal markets for crop and livestock inputs and outputs.
(b). Active (and inactive) community groups.
(c). Local prices for crop and livestock inputs and outputs.
(d). Regional, district, and village-wide extension and veterinary-service activities.
(e). Current government programs available to the village.

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[10]. Behnke and Kerven [1983] discuss the issue of identifying the appropriate farm unit for analysis.

4.2.4.4 Means Of Identifying The Socio-Economic And Institutional Constraints

Various survey formats can be used to obtain information about socio-economic and institutional conditions/constraints. Table 4.3 suggests the appropriate survey format and frequency for each factor identified above.

The following suggestions may be helpful when deciding which surveys to administer:

(a). Factors monitored by a yearly single-visit survey can be obtained through an End-of-Season Cooperators Survey. However, information on extension-service activities and current government programs can also be obtained through discussions with appropriate government officials.

(b). Factors monitored by a single-visit survey every five to ten years are usually obtained through single-topic surveys.

(c). Multiple-visit surveys performed every five to ten years are usually related to intensive case-studies.

TABLE 4.3: SURVEY FORMATS AND FREQUENCY FOR SOCIO-ECONOMIC AND INSTITUTIONAL CONDITION/CONSTRAINT FACTORS

FACTOR	TYPE OF SURVEY	FREQUENCY
I. SOCIO-ECONOMIC CONSTRAINTS:		
Definition of the household	Single-Visit	Initial/5 to 10 year update
Household size and labor available	Single-Visit	Initial/yearly monitor
Crop management practices	Single-Visit	Initial/yearly monitor
Division of household labor	Multiple-Visit (Weekly)	Initial/5 to 10 year update
Cattle and smallstock wealth	Single-Visit	Initial/yearly monitor
Draft type and access	Single-Visit	Initial/yearly monitor
On- and off-farm income sources and income flows	Multiple-Visit (Weekly)	Initial/5 to 10 year update
Capital resources	Single-Visit	Initial/5 to 10 year update
Participation in government programs	Single-Visit	Initial/yearly monitor
Adoption of new technologies	Single-Visit	Depends on technology introduced
Farmer decision making	Single-Visit	Initial/5 to 10 year update
Food consumption patterns	Multiple-Visit (Weekly/Monthly)	Initial/5 to 10 year update
Marketing patterns	Multiple-Visit (Monthly)	Initial/5 to 10 year update
Census baseline	Single-Visit	Initial/5 to 10 year update
II. INSTITUTIONAL CONDITIONS/CONSTRAINTS:		
Informal and formal markets	Single-Visit	Initial/yearly monitor
Community groups	Single-Visit	Initial/5 to 10 year update
Local prices	Single-Visit	Once or twice a year
Current government programs	Single-Visit	Initial/yearly monitor

4.2.4.5 Food Consumption (Nutritional) Perspective

One important objective of farming systems research is to improve the standard of living of rural (limited resource) households. The strategy often taken is to increase agricultural output and employment, and thus to increase incomes. "The critical empirical question is; do the increases in output and income which result from a project improve the nutritional status of individuals who are malnourished?" [Whelan, 1983: p. 264]. This is not necessarily an easy question to answer as there are many linkages between production and consumption which may be affected by farming systems research, and which may positively or negatively affect the nutritional status of the farm household.

In Botswana the harsh climate limits the number of crops which can be reliably grown, thus

limiting the ability of farming systems teams to manipulate crops either by crop type or by planting time to improve the nutritional situation for families. The general concern for most farmers is producing a larger quantity of food crops, but they are limited in the types of crops from which they can choose. Some possibilities do exist for improving the nutritional situation through the increased used of pulses (beans). There may also be room to improve the use of livestock products in the diet and to improve nutrition (both in variety and timing) through purchases made with receipts from the sale of livestock products or from receipts from off-farm employment.

4.2.4.6 Why Is A Food Consumption Perspective Important?

Frankenberger [1985: p. 11] gives two reasons why a food consumption perspective is essential in FSR.

> "First, given the importance of securing adequate family food supplies in the goal sets of small farmers, FSR efforts which ignore these goals are less likely to enhance the levels of well-being of project participants.
>
> Second, food consumption considerations help identify technological alternatives compatible with consumption preferences of farm families, thereby ensuring their likely acceptance."

4.2.4.7 Ways To Incorporate Food Consumption Perspectives Into Research

Frankenberger [1985: p. 11] identifies six linkages between production and consumption patterns which can be analyzed in order to include a food consumption perspective in the FSR. These are:

(a). ***Seasonality Of Production.*** In most areas of the world there is a seasonal dimension to agricultural production, food availability, malnutrition, human energy expenditure, incidence of disease and the terms of trade for the poor. Small farm families may suffer through periods of deprivation every year as a result of the adverse interaction of these seasonal aspects.

(b). ***Crop Mix And Minor Crops.*** As societies become more integrated into regional, national and international markets, non-food cash crops and non-indigenous food staples may replace some subsistence crops. The shift could have detrimental consumption effects (i.e., a decline in crop diversity, increased risk due to fluctuating markets, exaggerated seasonal cycles of plenty and want, elimination of wild plant food through herbicides, less land available for production of food crops, a breakdown of traditional food sharing networks, etc.).

(c). ***Income.*** Income can have an impact on consumption levels depending upon how regularly it is received (i.e., lump sums versus periodic), what form it is in (i.e., food versus cash) and who is the recipient in the household (i.e., women versus men). This linkage is strongly interrelated with crop mix and seasonality.

(d). ***The Role Of Women In Production.*** Women are often responsible for growing food crops and their income is generally used for food purchases. However, they are often neglected by agricultural extension services. In addition, increasing the agricultural labor demands on women through cash crop intervention may lead to:

i. Changes in cooking habits (i.e., fewer meals and/or quicker, less nutritious meals),
ii. Women planting less labor intensive and less nutritious food crops (i.e., cassava instead of yams), and
iii. Less time devoted to child care and breast feeding.

(e). ***Crop Labor Requirements***. The introduction of new cash crops may require more human energy input than previously grown crops, and the added energy requirement may be greater than the value of the output. These increased energy demands could also have negative nutritional effects on intra-household food distribution patterns if some members of the household require more food intake to meet the labor demands of the new crops.

(f). ***Market Prices And Seasonality***. Market prices and access can have an impact on consumption patterns of small farm households. For example, in most developing countries, high consumer food prices coincide with small farmer food shortages. In addition, government importing and exporting policies may adversely affect the prices of crops grown locally, keeping the purchasing power of small farmers low. Finally, market inefficiency and/or periodic market instability can place a region that is dependent on market purchased food in a vulnerable position.

Frankenberger [1985: p. 11] goes on to suggest four ways in which a consumption perspective can be integrated into the FSR process. These are:

(a). Through the incorporation of consumption concerns in target area selection, nutritionally at risk regions are more likely to participate in project activities.

(b). By including consumption considerations in diagnostic baseline studies, existing consumption patterns are better understood.

(c). Taking consumption concerns into account in formulating recommendation domains may ensure that nutritionally vulnerable households are considered in the design of intervention strategies for on-farm testing.

(d). Evaluating project performance by both production and consumption criteria will provide extension personnel with an idea of the potential consumption impact of various proposed technologies.

4.2.5 APPROACHES TO SUPPORT SYSTEMS DIAGNOSIS

4.2.5.1 Identification Of Support Systems

In farming systems research one of the elements identified as affecting the farming system is that of external institutions. This category is generally subdivided into the input side and the market or output side. Gilbert et al., [1980: p. 9] offer the following description of external institutions:

> "The two main types of institutions influencing farming decisions are the input supply system and markets where the farmers can sell or trade their commodities. On the input side, in the developing areas of the world, programs such as extension, credit, and input distribution systems are often financed and manned by government and, therefore, reflect its policies. On the farm product side, government may directly (e.g., marketing boards) or

indirectly (e.g., improving evacuation routes, transportation systems, etc.) influence the prices farmers receive."

In Botswana, input systems include informal trading between farm families and formal systems include village traders, cooperatives, the National Development Bank, and the Department of Agricultural Field Services. DAFS has the responsibility for providing both information (the traditional extension function) and for administering government programs; including drought relief, ARAP payments and seed distribution, ALDEP equipment programs, and certain credit programs.

Output markets consist of informal trading between families and formal markets including village traders, cooperatives, the Botswana Agricultural Marketing Board, and the Botswana Meat Commission.

Policy at the national level affects many of the components of this support system through policies which control trader prices, regulation of cooperative activities, design and implementation of agricultural programs, and control of prices paid for products.

4.2.5.2 How To Identify And Describe Support Systems

Information on the support system available to farmers, and farmer utilization of the support system can be obtained in a number of ways.

(a). Secondary data can be used to describe the support system, and may also provide information on farmer use of the system.

(b). Information on the support system and farmer utilization can be collected during informal reconnaissance surveys.

(c). Data collected during a formal baseline survey or during multiple visit surveys can also help to describe the support system.

(d). Specific one time formal or informal surveys can be used to describe elements of the support system. A chain survey may be of value in this latter case. In this technique the interviews start with the farmer, and are then administered to progressively higher levels in the support system, e.g., local traders, wholesalers, importers, government regulators, etc.

ATIP has used several of these methods for collecting information on the support system. For example, information on markets was collected in the Agricultural Baseline Survey of Tutume District [Miller and Seleka, 1985], and information on trading establishments [Baker, 1988B], and the provision of information through the DAFS [Baker, 1988A], were collected in single purpose surveys in the Mahalapye area.

4.2.5.3 Determining The Impact Of The Support System On Farmers

One of the important linkages between research and policy is the ability of the research system to feed information from the research system to those who formulate policy. Byerlee and Tripp [1988] point out that:

"An agricultural research system with a strong farmer orientation can provide at least two important types of information not readily available to policy

makers:

(a). Technical information related to physical and biological responses under farmer conditions, and
(b). Information on institutional constraints to effective use of appropriate technology at the farm level."

Information on the impact of the support system on farmers, both positive and negative, can be collected during multiple visit interviews or in single purpose interviews. ATIP has collected information on farmer use of government programs through annual Cooperating Farmer Surveys (for example, Bock [1988A]) and through single purpose surveys. A good example of this latter type of survey was the assessment of the Accelerated Rainfall Arable Production (ARAP) and Drought Relief (DR) programs carried out by a number of farming systems teams at the request of the Ministry of Agriculture [ATIP, ADNP and FSSR, 1988]. A more limited single purpose study was conducted to determine the demand for tractor plowing [Worman, 1985].

4.3 USEFUL REFERENCES

Section 4.1:

Andrew and Hildebrand, 1982: pp. 6-33.
Frankenberger and Walecka, 1987: pp. 99-104, 129-135, 211-221.
Mutsaers, Fisher, Vogel and Palada, 1986: p.13.
Shaner, Philipp and Schmehl, 1982: pp. 61-82.
Zandstra, 1985.

Section 4.2:

Amir and Knipscheer, 1989: pp. 11-20.
Anderson, Dillon and Hardaker, 1986.
ATIP, ADNP and FSSR, 1988.
Behnke, 1984.
Bernsten, Fitzhugh and Knipscheer, 1984.
Dent and Thornton, 1988.
Frankenberger, 1985.
Frankenberger and Walecka, 1987: pp. 43-50.
Gray, 1986.
Hyden, 1986.
Shaner, Philipp and Schmehl, 1982: pp. 231-232.

CHAPTER 5: DESIGN AND TESTING

5.1 PURPOSE AND INFORMATION SOUGHT

5.1.1 PURPOSE AND APPROACH

During the description and diagnostic research activities, scientists work together with farmers to assess the current farming systems and to identify -- and quantify where necessary -- the major constraints to, or opportunities for, increasing farm production and, as a result, farmers' welfare. After these constraints and/or opportunities have been prioritized, the next logical step is to design and test various approaches or technologies to overcome those constraints and/or exploit the opportunities. This, then, is the purpose of the design and testing activities.

5.1.1.1 Designing

The design work involves proposing new technologies to address constraints or opportunities identified in the description and diagnostic work. Design work mostly involves discussions and thinking. The process of thinking through the design phase was outlined in steps form in the last chapter (see steps (d) to (i) listed in Section 4.1.1)[1].

Usually the process involves the development of ideas. Those ideas are derived mainly from three sources (see Figure 1.3) namely farmers, experiment station research, and only when necessary, RMRI trials on farmers' fields[2]. In general, no actual field research is undertaken during the design stage. However, some field activity is required in the sense that farmers, other researchers and extension personnel need to be consulted for ideas on improved systems and equipment. The more ideas that can be collected, the better.

After gathering ideas on the priority topics, researchers and farmers need to work together to select the most promising ones for testing. Researchers can use their scientific knowledge to select the theoretically best options, and use the descriptive data to gauge which options are most likely to fit farmers' resources within the target areas. However, the farmers' judgement will also be important in determining which systems are most practical and socially acceptable within the target area. Thus the design activity should include farmers' input, and interaction among scientists of different disciplines. Generally, this activity is quite informal among scientists, and informal discussion sessions with groups of farmers are a good approach for obtaining farmer input. Gathering a broad range of ideas during the design activities will increase the interest of all parties involved in the testing, and will lead to a higher success rate among the technologies that are eventually tested.

Occasionally, it may be necessary to undertake a more formalized trial/survey activity before technologies can be designed for testing. However, these take time and should only be

[1]. An alternative description of important procedures for the design and testing activities is given by Shaner et al., [1982: 87-107].

[2]. Sometimes trials in the RMF, and FMFI format, which are usually associated with the testing stage, can stimulate ideas

undertaken when absolutely necessary since they delay implementation of the testing stage, the core activity of FSR work. The two types of more formalized activities that can arise are as follows:[3]

(a). Trials, usually done in an RMRI format, to determine cause-effect relationships, concerning which researchers have some uncertainty. In these circumstances researchers need to improve their understanding before they can suggest strategies for farmers to test, that will overcome the constraints that have been identified or take advantage of the opportunities that exist through exploiting flexibility in the farming system.

(b). Surveys, usually directed towards farmers, to quantify their attitudes, or preferences, are needed to help in prioritizing what should be tested. The need for this type of survey is most likely to arise with reference to points to include in designing equipment that will then need to be developed in prototype form for testing.

5.1.1.2 Testing

Once the best ideas have been selected, they will need to be tested. The ultimate objective of farming systems research is to produce new technology options that will be used by farmers to increase their productivity and incomes. It is very important that researchers keep this objective in mind during the testing activities. It is this objective that determines the type of testing which is carried out. Because of this objective, new production systems must be examined from a number of different perspectives. First of all, the new options must be examined to see if they do, in fact, increase farm production, make farm production more reliable, or improve the output per unit of the most limiting input. Additionally, because of the differences between research stations and farms, the new options must be shown to be effective under farmers' actual conditions, as well as on the research station. This is in fact one of the reasons for on-farm testing. But for farmers to use them, new options must also be practical -- that is, technically feasible for them -- profitable and socially acceptable, and must fit within the resources that they have available. Two examples are as follows:

(a). It is well known that winter plowing will help to increase crop grain yields. But farmers who own cattle do not apply the system because the soil is too hard for their animals to plow during winter. For them, the option is not practical.

(b). Most farmers know that applying phosphate fertilizer will increase their crop yields. When fertilizer is given to them free, they are very happy to apply it. However, when they have to purchase it, they know that unless the rainfall is very good, the increase in grain yield will not be enough to pay for the cost of the fertilizer. So they do not buy it. In some years, it is not profitable.

Once technology options are released through the extension system, it is up to the farmers themselves to decide whether or not to adopt them. They will only do this if the new options are practical, profitable and socially acceptable. To ensure that this is so, representative farmers must be included in the initial design and testing activities. Farmer groups -- both researcher and extension-oriented (see Section 13.1) -- can be used as a way

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[3]. Sometimes, as was mentioned in Section 4.2.2.2, these activities could have been implemented during diagnostic activities. Thus the distinction between diagnostic and design activities can become somewhat blurred. For example, the Steps-In-Technology Trial had both diagnostic and design features.

for technologies to be tested by farmers on their own. The opinions of these farmers need to be carefully considered, and, if necessary, the technology modified before it goes to the extension phase.

5.1.2 SETTING PRIORITIES

Setting priorities for the design and testing work is an extremely important activity, because the priorities will decide the primary direction of the research program. In this regard, much of the discussion in Section 4.1.4 is applicable. That section should be re-examined if the reader has an interest in this topic.

In summary, setting priorities means selecting the most important items for researchers to address. Because all farming systems are complex in nature, cooperation among scientists of different disciplines is necessary in order to identify the most important problems or the best opportunities for improvement. Since the local production systems have been developed by farmers, and are being used by farmers, their opinions on research priorities should be sought, and respected; especially since researchers also expect farmers to apply the results of the research.

Several other questions that need to be considered when deciding whether or not to initiate research on a particular topic include:

(a). How severe is the problem in terms of reducing farm productivity?
(b). How common is the problem among farm families in the target area?
(c). What potential is there for solving the problem?
(d). Are there potential areas for increasing farm production that are being under utilized at present?

5.2 APPROACHES TO CROP PRODUCTION TRIALS

Once improved production technology options have been designed, they need to be extensively tested within the target area. Based on these tests, the technologies are either discarded, modified and re-tested (i.e. if they seem promising but still need improvement) or taken to extension (i.e., if they are beneficial and acceptable to the farmers).

Much of this testing needs to be carried out with farmers, on their lands, within the target area, in order to determine which technologies work best in the target area, and to ensure that they are practical under farmers' conditions. On-farm research follows the same basic statistical theory as that applied on the research station. However, on farm research is done under somewhat different conditions from on-station research, and often has different evaluation methods and criteria. Therefore, the traditional on-station research trial formats need to be slightly modified before they are applied on-farm. Also, the trial designs used on-farm, under farmer implemented conditions (RMFI or FMFI), are often much simpler than those carried out on-station, so as to facilitate farmer understanding and implementation.

The important task of selecting villages and farmers to work with is discussed in Section 6.1, and some suggestions on good approaches for interacting with farmers are given in Section 6.3. Some other important issues relating to trials implementation are discussed in Section 5.2.3.

Regarding the types of trial designs commonly used in on-farm research, these range from extremely simple designs to designs which are quite complex. Selection of a particular

design usually depends on the trial objectives, with different types of trials being most appropriate for meeting different types of objectives. Before looking at some examples of common designs for undertaking crop production trials, the next section briefly considers the different trial formats that are possible.

5.2.1 TRIAL FORMATS

As has been discussed in some detail earlier (see Section 2.4), trials in FSR can be classified into three broad groups; namely researcher managed and researcher implemented (RMRI), researcher managed but farmer implemented (RMFI), and farmer managed and farmer implemented. A brief overview of the roles of the different formats is given in the following sub-sections:

5.2.1.1 RMRI Trials

This format is most commonly used in FSR during the design stage, when the objective is to determine whether a new technology will function, in a technical and biological sense, in the physical environment of a farmer's field. Because all of the work is handled by researchers, the trial design can be as large and complex as is needed to answer all the relevant questions. In general, formal, replicated trial designs are used in these trials.

5.2.1.2 RMFI Trials

The primary purpose of RMFI trials is to determine whether farmers can implement a particular technology, using their own resources, and to determine how much benefit the technology provides when this occurs. The benefit may be measured in many ways including grain yield, net profits, cash returns to farmers' labor, net production per unit of plowing time, etc. The participation by the farmer is essential in order to get a realistic picture of whether farmers will be able to implement the technology with the resources they possess, to develop a realistic economic picture, and to obtain initial farmer assessment of the technology.

At the RMFI level, researcher management is still required because the researchers need to collect basic data on what happens when farmers implement the new technology, and on the performance of the technology, or technologies, versus the farmers' own production system. Accurate descriptions of technology performance, and accurate estimates of values required for partial budget analysis, both require well designed and properly implemented trials, and a good deal of fairly detailed data collection.

The involvement of the farmer has a major impact on the design of RMFI trials. It is necessary to keep in mind that the farmer is not a paid, or unpaid, laborer. Rather, the farmer is an independent person who is trying to run a business (i.e., the farm). Hence the researcher should try not to take any more of the farmer's time than is absolutely necessary. For this reason, trials should not require more than a single day for planting. If the farmer is using draft animals for plowing, this will limit the size of the trial. The trial design should be simple enough that the farmer will understand clearly what the treatments are, and how they need to be implemented.

5.2.1.3 FMFI Trials

The primary purpose of FMFI trials is to determine how a technology will perform under farmer management, and to gather extensive farmer assessments of the technology, so that it can be modified if necessary, before it goes into the extension phase. Farmer assessments are generally collected through discussions, and through surveys that quantify farmers' opinions of the technology. The more farmer opinions collected in this activity, the better. One good way to handle these types of trials is through the use of farmer groups (see Section 13.1).

Because these trials are both farmer managed and implemented, they need to be extremely simple in design so that they can be implemented without any guidance from researchers. Where only farmers' assessments of a technology are required -- for example, with equipment trials -- no statistical design is used at all. Farmers simply try out the technology on a portion of their land, and report their observations. FMFI trials are usually restricted to simple comparisons of single technologies; for example, double plowing versus single plowing, fertilizer versus no fertilizer, etc. In these trials, all management decisions other than the specific treatment, are left for the farmer to decide.

5.2.2 CROP PRODUCTION TRIAL DESIGNS

Before looking at the possible trial designs, three important points that should be considered when planning trials are as follows:

(a). ***Experimental Versus Non-Experimental Variables.*** The design stage produces seemingly appropriate sets of improved practices for testing at the farm level. The following procedure is recommended for making decisions about the experimental and non-experimental variables[4]:

i. The experimental variables should consist of practices in which farmers' management is flexible, or where **ex ante** evaluation suggests that certain new practices would increase productivity. Flexibility in management is increased when there are under-utilized resources, while increasing productivity of variables is vital to breaking constraints.

ii. The feasible range of treatments for such variables is set by the flexibility that exists. For example, some flexibility could be introduced by assuming that the institutional support system could change. Then, it could, for example, be assumed that an institutional source of credit could be made available to supplement the cash flow of the farm business. The above remarks suggest that development of improved practices should usually consider the existing or definitely expected infrastructural support system.

iii. Non-experimental variables should be set at levels representative of local farm practice, and/or should be implemented by farmers themselves. The failure to take account this interaction between farmers' practices and recommendations is a neglected and crucial reason for poor adoption.

(b). ***Control Plots.*** It is important to remember that researchers and farmers need to compare treatments with something. Thus in all types of trials some form of control,

[4]. See also Section 2.4.3 for further discussion on this issue.

which "copies" the farmer's usual levels of the experimental variables, is generally used for the comparison.

(c). ***Recording Data.*** Although the following discussion concentrates on trial designs, it is important to remember that implementation requires that good records and data are collected either in field books or specially designed data collection sheets.

There are a number of possible trial designs that can be used in FSR work with crops. For convenience in presentation they can be divided into two major groups as follows:

(a). Those that involve replication of treatments within fields. These are most suitable for RMRI trials, while the simpler designs can be used in RMFI trials.

(b). Those that have no replication of treatments within fields. These very simple designs are used in FMFI trials.

The following sub-sections briefly outline the different types of trial designs.

5.2.2.1 Trial Designs Involving Replication Within Fields

Some experiments require accurate comparisons of several quite specific treatments. For example, a tillage trial might involve comparisons of several different tillage options, or a fertilizer trial might involve examining the effects of several different levels of fertilizer application, of both nitrogen and phosphate fertilizer. For the comparisons to be meaningful the treatments must be applied in a particular way, and at very specific times on each plot. To be sure of detecting important differences between the treatments, it is usually necessary for this type of trial to be replicated both within a farm, and across several farms, and often across years as well. Because of the need for precise treatment applications and replications, these types of trials generally require researcher management, either RMRI or RMFI. For these types of trials, the use of simple, formal trial designs are quite appropriate.

(a). ***Completely Randomized Design (CRD).*** The CRD is one of the simplest trial designs. When using the CRD with a field trial, the number of treatments and the number of replications per treatment are first decided. Then the appropriate number of plots are drawn, and the treatments are assigned randomly to all plots. This is usually done with a table of random numbers.

This type of design is only appropriate for experiments where plots cannot be meaningful grouped. An example would be where all plots are on the same soil type, the soil is of equal depth in all plots, and there is very little or no slope in the field. The CRD is the simplest design in terms of the analysis of the data, especially if some treatments are lost. There is less information lost with missing data in the CRD than with other designs.

The disadvantage of the CRD is that it is not very precise because all of the variation between experimental units is included in the experimental error term.

(b). ***The Randomized Complete Block Design (RCBD).*** The RCBD is used where experimental units -- that is, plots in field trials -- can be meaningfully grouped. For example, plots higher up a slope may be grouped together, and plots lower down the slope may be grouped together. Or, if soil depth varies from one end of an experimental area to the other, plots on the end with shallower soil may be grouped together and plots on the end with deeper soils may be grouped together. These

"groups" are generally referred to as "blocks". In the RCBD, since each block contains a complete set of treatments, these blocks can also be called replications, or "reps" for short. The reason for grouping the treatments this way is so that differences observed between treatments are more likely to be due to the treatments themselves, rather than the differences between experimental units.

The RCBD is one of the most commonly used designs for field trials. This is because differences exist in most fields, and using "blocks" helps to improve the precision of the experiment. It is also relatively simple to analyze so long as one can avoid missing data points. It should be noted, however, that when using the RCBD, the researcher must have some idea of what field differences he or she is blocking against, and lay out the trial accordingly.

(c). ***Split Plot Designs.*** A split plot refers to a trial plot which receives a certain treatment, and is then "split" or divided into sub-sections, to which different levels of another treatment are applied. For example, suppose an experiment is designed to examine the effect of irrigation on sorghum grain yields. Three treatments are included: no irrigation, moderate irrigation and heavy irrigation. Then suppose the researchers also wish to examine the effects of irrigation, with and without nitrogen fertilizer. Each of the irrigation treatment plots are "split". One half of each plot receives the nitrogen treatment, and the other half does not. In each replication, then, there will be one non-irrigated plot, one plot that receives moderate irrigation, and one with heavy irrigation. Additionally half of the area that receives no irrigation will receive nitrogen. The other half will not. Half of the plot that receives moderate irrigation will receive the nitrogen treatment and the other half will not. Half of the plot that receives heavy irrigation will also receive the nitrogen treatment, and the other half will not. The irrigation treatments have been "split" for different levels of nitrogen.

Split plot designs are commonly used when:

i. Large experimental areas are required for one treatment but not for others (e.g., irrigation treatments on different crop varieties).

ii. Researchers wish to include an additional factor in an experiment to increase the scope of the experiment (e.g., adding a fertilizer treatment to a trial involving several tillage treatments).

iii. Larger differences are expected from one factor than another (e.g., irrigation treatments on different sorghum varieties).

Split plot experiments are often a convenient approach for implementing experiments that involve the comparison of different levels of two or more factors. However, the designs and the analytic procedures are slightly more complicated than the CRD or RCBD. Researchers who are not used to working with this type of trial should consult the biometrician at DAR for assistance before developing a field lay-out, and especially when conducting the analysis.

In RMRI type trials, any of the above designs can be used satisfactorily in on-farm trials. However, in the case of RMFI trials, it is probably best to restrict trial designs to an RCBD or CRD, to restrict replications to two or a maximum of three per farm, and to restrict treatments to a maximum of four or five.

5.2.2.2 Trial Designs Without Replication Within Fields

In these types of trials, replication takes place across fields. The following three types of FMFI trials are commonly used in FSR work:

(a). ***Paired Comparisons.*** Using this approach, farmers implement a planned comparison in their field, on previously marked plots. This approach is generally used for simple comparisons; for example, with and without fertilizer, row planting versus broadcast planting, single plowing versus double plowing etc. However, it can also be used to test an "improved" system against the farmer's traditional system, for example, a system involving double plowing, row planting and phosphate fertilizer versus the traditional broadcast planting, single plowing, unfertilized system. Such trials are usually replicated across a number of farms, but not within a farm. This format usually requires that the same crop and variety be used for all paired comparisons, with the same seeding rate across trials and farms, and the same planting date for each plot in a pair. Then, aside from treatment variables, the management of the comparison follows the farmer's usual practices.

The number of treatments in each set of comparisons can also be expanded where it is necessary and appropriate. For example, the approach could be used for crop variety trials, where researchers wished to determine the best variety of a crop to recommend within a region. In this case, the comparison might include three or four new varieties, to be compared against the farmer's own. However, a different type of statistical analysis is required when treatments are expanded beyond a pair. It would be best to consult a biometrician at DAR on the most appropriate analytical technique.

The paired comparison format has been used extensively in Botswana for FMFI trials. It is appropriate for farmers because:

i. It is fairly simple to understand and implement.
ii. It generally does not require much of the farmer's time or management, because it is a small trial.
iii. The results are fairly clear and easy for farmers to interpret -- whether or not there has been any benefit from the "improved" treatment.

The format is also easy for researchers to apply over a large number of fields. Once the sites have been selected and marked prior to the start of the season, farmers can usually implement the treatments themselves, with researchers checking the progress in the regular group meetings, and/or visiting the fields at their convenience. When a set of this type of trials was managed through group meetings, farmers in the Tutume Agricultural District properly implemented about 100 comparisons in both the 1987-88 and 1988-89 seasons.

(b). ***Field Testing New Equipment Prototypes.*** One of the simplest trial formats commonly used in Botswana has been employed when testing new pieces of farm machinery. In this case, the equipment is simply used by several farmers within a region. No plot size is specified, and there are no replications required within a farm. The farmers are simply provided with the equipment, shown how to use it, and -- as long as they have an interest -- are requested to put it to use. Researchers then assess the performance and effectiveness of the equipment by:

i. Observing its operation in the field.
ii. Holding informal discussions with the farmers who use it.

iii. Conducting a formal survey with the farmers who use it.

The formal survey is used to obtain quantifiable data on farmers' opinions, the problems they encounter in using the equipment, their suggestions for improvements, and their judgments as to whether or not the equipment could benefit their farm operations.

This type of approach is particularly suited to testing types of equipment which have been used in other areas, and the researchers wish to introduce into the target area. In such cases, the design of the equipment is known to be effective, and the primary purpose for the tests is to determine whether the equipment is appropriate for farmers' systems and resources, and the environment in the target area.

An example of the use of this type of trial format occurred when a new type of donkey collar was introduced in the Francistown region. The collar had been manufactured in Kenya and was in general use there. It was tested by several farmers in the Francistown region. Both informal discussion and survey data showed that it was an improvement over the equipment they had been using up to that time [Bock, 1988B; Gray and Horspool, 1987]. After the study, local production of the collar was started by the Rural Industries Innovation Center (RIIC) in Kanye, and moved into the ALDEP extension program.

(c). *Superimposed Trials.* Superimposed trials can used to test relatively simple innovations under farmer management. In these trials, a treatment is superimposed in a plot or plots, on a farmer's field, after the farmer has started the initial crop husbandry work, usually after planting. The comparison in this case is generally between the farmer's own system, and that system plus an additional treatment, for example, an extra weeding, or a top dressing of nitrogen, etc. The treatment plot yields are compared with yields from an equal area of the field adjacent to the treatment plot. There may be more than one comparison per field, and comparisons are usually made in a number of fields[5].

This approach has been used to a limited extent in Botswana. It has appeal because it seems relatively simple at first glance. However, the amount of work involved is not really much less than any regular FMFI trial. The reason for this is that the researchers must spend time during the growing season, when they are usually quite busy anyway, travelling around examining fields until they find ones appropriate for their treatments. They still have to contact the farmers and discuss the trials, mark out plots, possibly assist with the treatments, supervise harvests and measure yields. Generally it is simpler to do the planning, hold discussions with farmers and mark plots prior to the on-set of the cropping season, particularly if the researchers have a large, on-going trials program which demands their attention during the cropping season.

5.2.3 GENERAL ISSUES IN TRIALS

There are a number of issues that have to be addressed if the trials are to answer the questions the researchers are asking in a satisfactory and resource efficient manner. Some of these are discussed in the following sub-sections.

[5]. This approach is discussed further elsewhere in the handbook (Section 2.4.4) and in Shaner et al., [1982: p.114].

5.2.3.1 Specifying Trial Objectives

Clearly defining trial objectives is perhaps the single most important activity in conducting a trial. The trial objectives are a statement explaining what the trial is supposed to achieve. Decisions regarding the trial design, the format (RMRI, RMFI or FMFI), the treatments to be included, the data that must be collected, etc., depend entirely upon the objectives of the trial. For this reason, before starting any trial activity, the researchers must agree on the exact objectives of the trial, and these must be written down. Only after that can the trial be designed and implemented. Beginning a trial without a clear idea of the purpose of the trial and exactly what questions need to be answered can result in a lot of wasted effort.

5.2.3.2 Choosing A Format To Fit Trial Objectives

Once the trial objectives have been clearly defined, the trial design can be formulated. To decide whether a trial should be RMRI, RMFI or FMFI, researchers will need to consider the type of information required from the trial. If only technical data are required -- such as stand establishment, or grain yield -- the trial can probably be implemented as RMRI. However, if farmer assessment is required, or if farmers own resources need to be involved, then the trial will need to be implemented as either RMFI or FMFI. The choice between RMFI and FMFI will largely depend on the complexity of the trial design, the number of treatments and replications per location, and the type of data required. The more complex the trial, and the more technical data are required, the more researcher management will be needed.

5.2.3.3 The Need For Regular Field Visits

It has been said that the best "fertilizer" a farmer can apply to the crop is foot prints in the field. That is to say that regular field visits are extremely important for ensuring a good crop. The same applies to good trials.

Well trained technicians can be very helpful in implementing trials and collecting data, but their performance will only be as good as their supervision. Regular visits are important for several reasons:

(a). It is only through regular visits that researchers will understand what has happened in the trial through the season, and be able to correctly interpret the results.

(b). It is only through these visits that the researchers can observe and guide the performance of the technicians and farmers -- in the case of researcher managed trials -- and be sure the trials are properly implemented and that the data are properly collected.

(c). For cropping trials, with researcher management, it is particularly important that researchers are present when treatments are being applied, and when the trials are harvested. Mistakes during either of these activities could greatly affect trial results and lead to either misinformation being produced, or the loss of a season's work.

(d). Lastly, in researcher managed trials, it is only through regular field visits that researchers can identify problems in a timely manner (e.g., developing weed infestations, developing insect problems, etc.), and deal with them appropriately.

Thus, particularly in researcher managed trials, there is no substitute for regular visits by senior researchers. Probably visiting once a week is a minimum. Even with FMFI trials, senior researchers must visit each trial occasionally to ensure that the trials are valid for analysis, and to understand what has occurred so as to interpret the results correctly.

5.2.3.4 Limiting Research Topics To Fit Research Resources

Researcher managed trials (RMRI or RMFI) require a good deal of attention from senior researchers. Aside from being present during critical implementation stages, researchers must make regular field visits to each trial site throughout the season. In addition, much time is required to plan the trials, collect the necessary inputs, arrange for tillage, planting, weeding, spraying and other activities. Trials also require training and supervision of the technicians, and often involve a lot of discussions with farmers. Where research teams share resources -- for example, vehicles or technicians that perform work for agronomists, economists and animal scientists at the same time -- care must also be taken to ensure that individual researchers do not monopolize the resources to the detriment of other disciplines.

There are always more problems than researchers have time or resources to address. However, because of all the above requirements for researcher managed trials, researchers must be very careful in planning their work load for the season. Teams should work together to set research priorities, and carefully consider the amount of time and resources that will be required for each planned activity. Taking on too much work will result either in some activities being dropped during the season, or some work being lost due to insufficient attention, and the quality of the research will generally be reduced. Taking on less work than is possible will result in a waste of resources. Careful planning and experience will be the best tools for developing optimum work loads.

5.2.3.5 Expanding Research Capacity With Farmer Testing Groups

In contrast to researcher managed trials, FMFI trials require much less of the researchers' time during the season. Under this format, researchers are involved in planning the trials with the farmers, in collecting and supplying the necessary inputs for the trials, and in monitoring the progress of the trials. But this is much less work per trial than is required for day-to-day management. To reap the full benefit from FMFI trials, it is necessary for researchers and farmers to have frequent discussions; these discussions can be efficiently handled through regular group meetings. Because farmers are providing the day-to-day management of the trials, researchers can visit the trials at their convenience, rather than having to visit at specific critical periods. This also helps researchers to spread out their work load and improve efficiency.

Many technology items require only farmer testing and some minor adaptations before they are ready for extension, for example, the Maun cultivator, the Kenya donkey collar, etc. Other items, such as new cowpea varieties simply require farmer testing before final selections are made for extension. For technology items that are new to an area and only require farmer evaluations and minor adaptations, farmer testing groups can be an extremely efficient approach. A detailed description of how this approach has been used in Botswana is presented later in the handbook (see Section 13.1).

5.3 APPROACHES TO LIVESTOCK TRIALS

5.3.1 CHARACTERISTICS OF THE LIVESTOCK EXPERIMENTAL UNIT

Animals are complex biological systems involving many elements such as health, nutrition, genetics, reproduction and behavior. The multiple uses of animals and the multiple ways they interact with other components of the farming system, all make trials work with animals very complicated. Bernsten et al., [1984: pp. 98-100] have identified a number of major characteristics of livestock which make design and testing of livestock systems more complicated than for cropping systems.

(a). ***Mobility.*** While crops are planted, reproduce and mature at a single location, animals are mobile -- except under confinement systems. This makes it difficult to describe environment-livestock interactions and to measure and/or control factors not included as treatments.

(b). ***Life Cycle Duration.*** Food crops, except tubers, typically mature in three to four months, while the reproductive cycle of ruminants extends over a year or longer. Not only does this increase the cost of experimentation, experimental units may die or may be sold before the trial is completed.

(c). ***Life Cycle Synchronization.*** Crops are planted as a unit and harvested as a unit. The production of many animal products, however, is not synchronized and occurs at different times or time intervals. To be able to find sufficient animals of the same age group, and in the same production phase, is often troublesome.

(d). ***Multiple Outputs.*** Crops generally produce a primary output such as grain or tubers, and a secondary crop residue output. In contrast, animals such as cattle, may produce several outputs of economic value including manure, meat, hair/hides, milk, and draft power. This makes it difficult to describe the system, to measure the impact of the treatments, and to evaluate the economic impact of an intervention.

(e). ***Non-Market Inputs And Outputs.*** Food crop production systems typically use inputs and produce outputs for which there is a market and a price. On the other hand, livestock production systems typically depend on inputs such as child labor and crop residue, and produce outputs like manure for which there may be no ready markets. Other outputs, such as risk management, capital accumulation, and ceremonial functions -- common to animals -- are extremely hard to measure.

(f). ***Size Of Experimental Unit.*** Individual plants are small and can be easily manipulated in field trials that affect only a small proportion of the producer's field. In contrast, because animals are large, and on small farms are few in number, controlled trials and interventions involving producer-owned livestock may expose the producer to unacceptable levels of risk.

(g). ***Producer Attitudes.*** While producers do not develop emotional relationships with crops, livestock producers often become attached to their animals. Also, religious taboos and customs may make it difficult to cull, castrate, and earmark livestock.

(h). ***Management Variability.*** Crop management practices are a major source of variability in on-farm crop trials. Yet, this is more of a problem when conducting livestock trials due to the longer life cycle over which a greater number of critical management decisions must be made. This makes it difficult to observe the effects of an experimental treatment.

(i). ***Number Of Observation Units.*** Crop trial results are measured in yield-production per hectare. No matter how small the trial plot, the yield estimate is always the average of many individual plants. In the small farmer setting, livestock performance is measured as production per animal. Consequently, statistical variability of treatments between groups tends to be greater than between; for example, fertilizer treatments.

"Design and testing in livestock research must carefully take into consideration each of these factors" [Bernsten et al., 1984: p. 100]. Table 5.1 summarizes these characteristics and indicates strategies and techniques for working with the problems.

5.3.2 TESTING WITHIN CROP-LIVESTOCK SYSTEMS

Testing of technology alternatives, within the crop-livestock system, may be carried out on a single management component -- component technology research -- or on a combination of technologies which may involve both crop and animal production techniques. According to Zandstra [1985: p. 173] the objectives of the testing phase are:

(a). To measure the performance of alternative technologies in the farm environment.

(b). To compare alternative component technologies and production systems with those presently used by farmers in terms of biological productivity, farm resource use efficiencies, and farmers' preference.

(c). To identify labor, cash, and agricultural input requirements of the alternative technology.

(d). To identify resource conflicts at the farm or community level that may be caused by the alternative technology.

Zandstra [1985: pp. 173-174] provides some additional points on testing component technologies. In the design phase researchers identify the appropriate factors and input levels to be tested. When conducting the test, management used on all factors should either be as designed in the alternative system, or should adhere to the farmers' management. Due to the complexity of working with animals, it is important that experimental designs be chosen so that as many non-treatment effects as possible can be removed by statistical analysis. Because of the high cost and operational complexities of animal trials, careful and exhaustive analyses are warranted. In addition to establishing treatment differences, the analyses should simulate the impact of the different treatments on the whole production system. An economic analysis, including partial budget analysis, is also desirable and may include costs and benefits for the system as a whole.

If a number of major changes are being introduced in an alternative crop-livestock system, the situation is even more complicated. One approach which can be taken in this situation, is to use a unit farm, where a suitable farmer is selected to "allow" his farm to be modified at the researcher's cost, and the test is run within the farm environment. Because the test is researcher managed and implemented, it may lose its "farmer character" [Zandstra, 1985: p. 176].

TABLE 5.1: SOME CHARACTERISTICS OF LIVESTOCK AND THEIR IMPLICATIONS AND STRATEGIES FOR ON-FARM TESTING

CHARACTERISTICS	IMPLICATIONS	STRATEGIES & TECHNIQUES
Mobility	Difficult to measure and control non-experimental variables	Subjective evaluation (eye balling) by farmer, researcher, trader or buyer Interviewing persons keeping, owning or monitoring animals Ear tagging or using some other means of identification Moving feed to animals
Life Cycle Duration	Increases costs and likelihood of losing experimental units	Recall surveys among farmers Simulation modelling Combination of cross-sectional and longitudinal analysis
Life Cycle Synchronization	Difficult to find comparable units	Total live weight per farm Production indices (kilograms weight produced/kilogram weight maintained) Internal indices (parturition interval, lactation period) Adjusting milk production to account for calving date variability
Multiple Outputs	Difficult to measure and value treatment effect	List outputs and alternative trade offs Determine value by: level of management, market, or farmers own assessment based on interviews
Non-market Inputs/Outputs	Difficult to value input/output	Labor: opportunity costs Survey of "laborers", measuring skills Measuring forage intake with two measurements: before and after Surveying farmers for determination of value Valuing manure as an example: (a). NPK value (chemical fertilizers used); (b). (market) value of tethering animals; (c). fuel equivalent value; (d). measurement of crop yield increment due to manure
Experimental Unit Size	Increases cost, risk to cooperator	Work with groups of farmers rather than individual farmers Introduce risk insurance provision Use proxy measurements, such as heart girth, instead of weighing
Producer Attitudes	Difficult to cull, castrate, ear marking	Need to be identified initially but difficult to quantify
Management Variability	Difficult to isolate treatment effect	Comparing two treatments on same farm (difficult because of lack of enough animals and cumbersome for farmer) Comparing before/after treatment by same farmer Compare two or more farmers (requires several farms and is more costly
Observation Units	Large statistical variability	See strategies under management variability Quantify normal death loss when developing test Experimental design must allow for loss of experimental unit
Ownership Determination	Joint management	Outputs: See above strategy on multiple outputs Determine decision making process Inputs: commercial land/pasture

Source: Caldwell and Walecka [1987: pp.257-259].

5.3.3 SOME SPECIFIC CONSIDERATIONS

5.3.3.1 Farmer Participation

Zandstra [1985: p. 174] identifies five ways that farmers can be involved in animal trials. These are:

(a). As observers, where the researcher designs and executes a (RMRI) trial on the farmer's land or with her/his animals, often through a rental agreement.

(b). As implementor of a test designed by the researcher. The farmer conducts all operations (RMFI) using his/her resources and animals, often augmented by production inputs or implements, and with supervision from the researcher.

(c). As a participant in the design of the trial and its execution under (b) (RMFI).

(d). As an originator of the test, through partial or complete adoption of a recommendation, using her/his own means to obtain additional inputs that may be required due to the production infrastructure specifically designed for the introduction of the new technology (pilot production program) (FMFI).

(e). As an originator of the test without access to special institutional arrangements (FMFI).

Tests (b) and (c) reflect the farmer's implementation, but are usually influenced by the researchers continuous contact; while tests (d) and (e) provide a more realistic estimate of the performance of the new technology, under farmer conditions.

ATIP has conducted livestock trials under tests (a), (b) and (d). Due to the complexity and possibly farmer-perceived risk of livestock trials, the RMFI trials have not been very successful. ATIP has found that animal trials are generally more successful if they are researcher managed and implemented, or if they are farmer managed and implemented. The latter type of trial usually involves only minor changes whose value has been well demonstrated to the farmers. For us, the RMFI trial format has proved to be much more effective for crop trials than for animal trials.

5.3.3.2 On-Station (OSR) Versus On-Farm Research (OFR)

It is generally agreed that livestock trials involve more of a risk for the farmer than do crop trials because they affect the limited number of livestock owned by the farming family, and because they generally take place over a longer period of time. So that farmer risk is minimized, it is most important that basic research affecting a trial be completed on-station before the trial is moved to the farm.

A 1985 conference in Addis Ababa, Ethiopia [FSSP, 1986: pp. 5-7] discussed the appropriate roles for on-station and on-farm research. The conference participants concluded that:

> "On-station research should focus on testing higher yielding variants of old enterprises (e.g., from other countries) or testing new enterprises as suggested by **ex ante** analysis, and by on-farm research. Because this kind of research (introducing new enterprises or improving old ones) has to be more controlled than OFR, it should be done on-station before OFR, unless the technology is well established and unless there are reasonable grounds to believe that OSR can be omitted."

The participants also identified five roles for on-farm research [FSSP, 1986: p. 5]:

(a). To give an **ex ante** description of the production systems, and to identify relevant problems for on-station research.
(b). To verify on-station results.

(c). To provide a continuing flow of information to on-station programs.
(d). To test new technologies under farmers' conditions.
(e). To demonstrate improved technologies to farmers and extension personnel.

Our experience supports the greater role of on-station research in the livestock area. Some reasons include:

(a). Compared to crop trials, there is more frequent monitoring required for livestock trials, which increases travel costs for on-farm research.

(b). Because animals do not care for themselves and do not stay in one place like plants, the results are likely to be less accurate on-farm, compared to the more controlled environment of the station.

(c). In working with livestock, laboratory facilities may be more important than in working with plants. This is because there are fewer animals involved, and the loss of an animal is a major event.

(d). Laboratory facilities, which are used to conduct research on blood samples and in diagnoses of diseases, are superior at a station, and there are generally fewer problems in transporting specimens to the laboratory from an on-station trial.

The other side of the coin is that, unless extreme care has been taken in the diagnostic phase -- especially in areas like animal health, biased data may be used to determine priorities. What is actually a big problem at the village level may never be reported to central research stations because the farmers don't know its a problem, don't recognize it as a problem, or think it is something else all together. For example, farmers understand that heartwater kills stock, but don't know it by that name or recognize that ticks transmit it. Thus, it is important, where possible, that professionals in the disease business, have some involvement in the diagnostic phase.

5.3.3.3 Risk Of Livestock Loss

Farmer managed livestock experiments should take place in the farmer managed setting, with farmer-provided livestock. However, when farmers have very limited livestock resources, and each animal is valuable, it may be necessary to reduce the amount of farmer risk in order to encourage participation. If there is any risk to the animals' health, even if it is only minimal, it may be necessary to provide a guarantee of replacement if the animal is incapacitated or dies [Shaner et al., 1982: p. 121].

Additionally, if the researchers are going to conduct research either by providing animals to farmers (a new breed), or through researcher implemented animal trials, it is important to be certain that the farmer or research field staff are capable of handling the animals. They must also be willing to take on the day-to-day responsibility of animal care, particularly in a confined or semi-confined trial situation. In the case of research staff, they must be made aware that animal care is a daily responsibility (particularly with confined animals), and that someone must perform the daily chores whether it is a public holiday or not. This may necessitate special administrative arrangements to pay overtime or otherwise compensate staff for the extra time.

5.4 EVALUATION[6]

5.4.1 THE FIVE TYPES OF EVALUATIONS

There are three types of evaluation which can be made on a new technology. These are:

(a). Technological evaluation which is performed by the agronomist or animal scientists from the farming systems team and determines if the new technology is practical in a biological evaluation, i.e., does the farmer receive a greater yield or more animal product when using the technology.

(b). Economic evaluation determines if the farmer will receive a greater economic return from the technology? In a sense, part of the economic evaluation is a financial assessment as to whether the farmer has enough funds available, or can acquire the funds by borrowing them or receiving a government subsidy, to implement the new technology.

(c). Social evaluation is used to determine if the technology is acceptable within the household (intra-household) and overall village (inter-household) situation. Social evaluation answers questions about which members of the household benefit from a technology and whether there are village taboos which would keep farmers from using the technology. Another consideration in the social evaluation is an environmental impact assessment, i.e., are there likely to be long-term beneficial or harmful effects to using a new technology.

Farming systems teams make all of these evaluations. Some are made formally -- usually the technological and economic evaluations. The others may be made formally or informally by the researchers in deciding if a new technology is useful and acceptable to farmers.

5.4.2 KEYS TO EVALUATION

The ultimate success of a new farming technology depends on farmer evaluation, acceptance, adoption, and sustained use. Thus, the farming systems team must evaluate new technologies, using the five types of evaluation listed above, for their acceptability to farmers, and farming households. Because the technologies must be acceptable to farmers, it is important to understand the farming household members' goals, and incentives, farming and non-farming activities, and available resources and constraints. Much of the evaluation hinges on selecting appropriate socio-economic evaluation criteria. A poor choice of criteria can lead to incorrect conclusions about the viability of the technologies being considered.

To help evaluate a technology from the farmer's point of view, seven basic questions need to be asked [Caldwell and Walecka, 1987: pp. 21-23]:

(a). Is the problem to be solved important to the farmer? A problem may appear to be important from the researcher's perspective, but not from the farmer's.

(b). Do farmers understand the trials? Technologies building on small changes in the existing system, are probably most easily understood.

(c). Do farmers have the time, inputs, and labor required for the improved technology?

Material in this section has been excerpted from [Caldwell and Walecka, 1987].

Farmers evaluate the resource requirements of a new technology not only in terms of whether they have or can secure the necessary resources, but also in terms of the competing demands for the resources. In addition, different family members control different resources, and so may view the technology differently.

(d). Does the proposed technology make sense within the present farming system? A change in one part of the farming system generally causes changes in other parts of the system. How will these secondary changes impact the system as a whole?

(e). Is the mood in the region favorable for investing in new technologies or crops? This may depend on how farmers view the economic and social situation in general.

(f). Is the proposed change compatible with local preferences, beliefs, or community sanctions? Tastes and color in foods, superstitions, the relation of the farming system to larger community values and activities, all can effect the acceptance of a new technology.

(g). Do farmers believe the technology will hold up over the long-term?

A number of key factors must be considered when determining the evaluation criteria. Some of these include [Caldwell and Walecka, 1987: p. 25]:

(a). Goals of the household and of individual household members.
(b). Scarce resources (time, labor, cash, land, animals, etc.).
(c). Probability of returns being less than a minimum acceptable level (risk).
(d). Control and distribution of inputs and benefits.
(e). Possible effects on other enterprises and on overall household production, consumption, and welfare.
(f). Wage employment opportunities.
(g). Access to credit, supplies, information.
(h). Community goals.
(i). Cultural and social factors.
(j). Government policy.

Clearly more than one evaluation criterion will be needed to address all of these factors. What are some of the economic and social criteria which may be considered?

5.4.3 ECONOMIC CRITERIA AND METHODS OF EX ANTE ECONOMIC ANALYSIS

In Botswana, most farming households produce a mix of products for household use, and sometimes for selling. Livestock (cattle or small stock) may be sold while basic grain production is, if not subsistence production, at least substitution production.[7] Some of the economic criteria used by a farming household in evaluating a new technology include:

(a). Labor needs for traditional food crops which may conflict with labor needs for the

Subsistence production is when a family must produce a certain quantity of basic food or go hungry. Substitution production is when a family has outside resources (remittances, drought relief, etc.) and will substitute family produced food for food which would have been bought in the absence of family production. Many Botswana families fall into this latter category.

proposed technology.

(b). Cash needs for food or for inputs for food crop production at the same time as the proposed technology.

(c). Effects of the proposed technology on allocation of land area for food crops or animals.

(d). Effects of the proposed technology on wild crops, animals or fish used for food.

(e). Effects of increased yield from the proposed technology on supply and prices in the community as a whole.

Some of the methods of economic analysis which we can use before a trial (**ex ante** analysis) to identify possible positive and negative effects of a new technology include:

(a). Partial budget analysis to compare anticipated increased costs with increased benefits.

(b). Projected benefit/cost ratios. Does any one technology show a substantially higher ratio than others?

(c). Sensitivity analysis to examine possible changes in the impact of technologies depending on changes in costs of inputs and/or prices of products.

(d). Analysis of input constraints and policy situation.

(e). Studies of market opportunities and marketing systems. Increased production may increase marketing problems or force down local prices.

(f). Review of consumption characteristics of different technologies may identify economic or technical trade-offs.

Generally, an economic analysis must be carried out on traditional technologies, as well as on new technologies, in order to compare the technologies and to identify changes in the whole farm system caused by changing one part of the system.

5.4.4 SOCIAL CRITERIA

Because household members are also members of the community and various groups within the community, social criteria include both effects within the household (**intra-household**) and across households in the village as a whole (**inter-household**). Some intra-household social criteria include:

(a). Effects of the proposed technology on other household activities. For example, would more frequent weeding reduce time available for child care?

(b). Differences in impact of the new technology on various household members. Does a technology which decreases work for the male household members increase work for the female members?

(c). Effects of changes in the trial crop or animal production on other crop and animal production sub-systems.

Other social criteria involve inter-household relations. These may involve changes within the community if new technologies are adopted. Some of these criteria include:

(a). Effects of proposed technologies on labor-sharing or food-sharing networks. For example, does the increased plowing time required for double plowing mean that the family traction will not be available to other members of the extended family?

(b). Effects of proposed technologies on differences in power and status among different people in the community.

Some of the community-based social criteria involve preferences and taboos. For example:

(a). Cultural or religious preferences for a specific crop or animal management practices. (The practice of keeping animals as a store of wealth to be used in a time of need, rather than being sold on a regular basis.)

(b). Cultural or religious taboos against specific crop management practices.

Social criteria can also effect economic and agronomic criteria. The use of cattle as a store of wealth means that farmers may not want to reduce their value by using them as traction animals.

As is emphasized elsewhere in the handbook (see Section 5.5.2), another part of the societal evaluation is to determine whether the proposed technologies contribute positively -- or least do not have a negative impact on -- the sustainability of the land in the long-run.

5.4.5 CONSUMPTION CRITERIA

Closely related to both economic and social criteria (and probably a sub-set of both) are consumption criteria. Two consumption criteria are:

(a). ***Acceptability Of Products.*** Where a new technology changes consumption characteristics from traditional technologies, there may be questions of acceptability. For example, is yellow maize as acceptable as white maize for porridge?

(b). ***Effect On Household Food Availability And Accessibility.*** The overall availability and accessibility of food to households as well as intra-household distribution may be altered by a new technology. For example, a shift from food crops to non-food crops may lower the amount of food available to the farm family. This happens when cash from the non-food crops is not used to replace the food not grown because the land shifted from a food crop to a non-food crop.

5.5 FORMULATING RECOMMENDATIONS

In this section the following are briefly discussed:

(a). Evaluation criteria that need to be considered in drawing up a recommendation -- both from the viewpoint of the farmer (private individual) and society as a whole.

(b). Additional information that should be included in official recommendations (**Agrifacts**) that will help make the technologies more useful by indicating when the technology is likely to be most appropriate (targeting information), and acceptable to more farmers through the inclusion of conditional clauses.

(3). A discussion on the type of information that is likely to be acceptable in approving recommendations.

5.5.1 SUITABLE EVALUATION CRITERIA -- FARMER VIEWPOINT

The primary issue is to ensure that effective evaluation takes place before technologies are recommended for dissemination by the extension service. Obviously the best test of the value of a technology is the degree of farmer adoption that occurs. Unfortunately such **ex post** (after the event) monitoring is too late to prevent wasted investment in extension

training, and in support and infrastructure services developed to handle anticipated increases in production. Therefore farming systems teams try to evaluate the value of the technology **ex ante** or before it is widely disseminated to the mass of small farmers. FSR attempts to assess the value of the technology as a part of its development. A favorable assessment is essential if an official recommendation or **Agrifact** is to be developed. There are three important points in determining the success of this **ex ante** evaluation. These are:

(a). The criteria used should be those which will be used by farmers in the target group. These are often difficult to identify.
(b). Farmer assessment is potentially an important substitute for formal economic analysis.
(c). The balance between an evaluation based on the criteria used by local farmers and a societal evaluation is a difficult one to strike.

Farmers will use criteria of two types:

(a). Whether they are **able** to adopt. Three factors important in determining this are:

i. Is it technically feasible for the farmers to adopt the technology, that is, are the necessary inputs readily available?

ii. Is the technology likely to be economically viable (profitable and dependable) for the farmers to adopt at the levels that will be beneficial to them? In this connection it is important to be sure that the proposed technology is more profitable, and hopefully more dependable, than the one it is designed to replace. In comparing technologies it is important to determine that the proposed improvement increases the return to the most limiting factor. For most farmers in Botswana, labor or draft power is probably more limiting than land. Therefore, in assessing economic viability, it is more important to look at the relative returns, and dependability of those returns, in terms of the return per hour of labor or draft used during the most constraining period -- the plowing/planting bottleneck period.

iii. Is the technology likely to be socially acceptable to the farming families? For some farming families who, for example share draft power, any proposed improved technologies that require more intensive use of draft power may not be acceptable because the potential for sharing may be decreased.

(b). Whether they are **willing** to adopt. Broadly speaking, will farmers be better able to achieve their goals by using the improved technology? The criteria on which they will decide their willingness to adopt are often difficult to determine. Factors such as the balance between preferred foodstuffs and returns to labor during one particular period of the season can be important criteria in determining this. Such factors are particularly difficult for those of us who are 'conditioned' to an experimental method which deals basically in weight per unit area of land to relate to. Indeed, several such criteria may have to be brought to bear on a single proposed change. For example, staggered planting as a practice may indicate water, labor or draft power scarcity; risk management; and a preference for a prolonged supply of a certain type of fresh food -- all at the same time. There is little chance of weighing these correctly in an economic analysis under the condition in which most Botswana farmers operate.

This difficulty in second guessing the balance in farmer evaluation criteria has often prompted FSR practitioners to argue for farmer assessment as a practical approach to technology evaluation. The FSR phase of technology development is in farmers' fields, with

farmers on the spot. Yet, to date, the devices developed and used for farmer assessment are rudimentary. Harrington [1980] noted that farmer assessment is likely to be useful when:

(a). Farmers have had little previous experience with the components of the new technology, and therefore cannot be expected to provide useful information in an **ex ante** survey.
(b). A knowledge of a recommended technology is needed to focus the questions regarding farmers' experience because there are many solutions to farmers' problems.
(c). The farming system is difficult to simulate in a formal model.
(d). **Ex ante** survey work was not well conducted.

We would go further than this; we are convinced that this is a vital area for FSR. We need to develop improved methods for routine farmer assessment of technologies. As we have already discussed, we try and ensure this in two ways:

(a). By using different types of trials reflecting varying degrees of commitment on the part of farmers.
(b). By using farmer groups in assessing the values of the different types of technologies -- including work done at the RMRI level.[8]

This emphasis on individual farmer's criteria for technology evaluation ignores the possible impact on other farmers, and on broader societal issues. Problems with reference to this are briefly discussed in the next section.

5.5.2 INCORPORATING SOCIETAL GOALS[9]

As has been repeatedly emphasized, the primary objective of farming systems research is to improve the well-being of individual farming families by increasing the overall productivity of the farming system. This is done in the context of both private and societal goals, given the constraints and potentials imposed by the determinants of the existing farming system. However, including societal goals in FSR has been difficult to achieve. Four reasons for this are:

(a). The primary effort of farming systems research has been to respond to the "felt" needs articulated by farmers. The closer farmers are to the survival level, the more likely these needs will demand fulfillment in the short-term (e.g., producing enough food to survive until next year). As a result, farmers will be less concerned about environmental degradation in the long-term.

(b). Because of responding to the "felt" needs of farmers, there is generally a short-run

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[8]. For example, this has been done in the Rainfall Runoff Management (RRM) work at Mahalapye. In order to obtain farmer assessment in this RMRI trial, a group of farmers were brought together at the trial site and the treatments explained to them by a team of sociologists and agronomists. Following this a series of questions was asked by the team to obtain farmers' opinions. Some of the questions asked were formulated by the team before the meeting.

[9]. Discussion in this section is confined to the issue of sustainability. There are of course other social criteria that are also important in the evaluation process, such as the potential effect of the proposed technologies on intra- and inter-household relationships (see Section 5.4.4).

focus to much of the farming systems research. This is in contrast to a long-run orientation in which societal impacts become more crucial. The short-term focus, combined with the methodological complexity of incorporating societal evaluation criteria, and the time required in deriving such societal impact evaluations has meant that FSR has played a limited role in this area. Emphasis on long-term evaluation has largely been confined to subjective **ex ante** evaluations. Such evaluations influence choices of problems to work with and the solutions to be advocated.

(c). Most farming systems research, due to its institutional affiliation, tends to concentrate on the development of relevant improved technology. It is possible to develop technologies that do not have a negative impact on the environment -- particularly the agro-ecological environment such as soils and to a much lesser extent, the socio-economic environment in the equitable distribution of benefits. However, it is the implementation of relevant policy/support systems that play an even more important role in making sure societal goals are fulfilled.

(d). Much farming systems work has been done with an externally funded project format. Projects tend to be of limited duration, and so there is a tendency to choose technologies that will show immediate results, and leave the long-term questions for those who are not limited to a few years of research. Many agencies which fund projects are wanting to see immediate results and so encourage research aimed at short-term improvements.

While recognizing the dilemmas implied by the above discussion, it is important to bear in mind that what is done now by the current generation of farmers has a bearing on what is possible in the future. A prime example of this is the issue of environmental stability -- recognizing the negative impact of environmental degradation on the livelihood of future farming families and possibly on the whole of society.

Current adoption of technologies and implementation of support programs can have either negative or positive influences on environmental stability. Hopefully, as discussed above, technologies developed by researchers are being screened **ex ante** for their possible environmental impact. In most countries there is an explicit concern for conserving the productivity of the soil. As suggested above, the closer farmers are to the subsistence level the more concerned they are about survival until next year, and the less concerned they are about maintaining environmental stability for future generations. Consequently, as was emphasized earlier (see Section 3.4.2.2) conservation measures by themselves are unlikely to be very attractive to most limited-resource farmers. Production does not have to be undertaken at the expense of conservation, as long as the people responsible for developing technologies and policy support programs take conservation into consideration.

The objective of this discussion is to simply emphasize the need to be aware of the possible conflict between farmers' and societal needs, and the importance of technology and policies supporting each other in developing a system of agriculture that will help provide satisfactory levels of living not only for the current generation of farmers, but also for future generations. Unfortunately, at present we lack the appropriate methodologies for handling these types of the issues.

5.5.3 INCORPORATION OF CONDITIONAL CLAUSES AND TARGETING INFORMATION

As has already been indicated several times, there is a great deal of variation in the natural (technical) environment that farmers face, and in the socio-economic characteristics or

resources they possess. In spite of this variation, standardized technological packages are often recommended. It is not altogether surprising that, where technological packages have been disseminated, many farmers have adopted components rather than the complete package. In such cases, there is often little advice available on what farmers should do. For example, should they put a top dressing of fertilizer on when they don't weed? The return from the limited research resources[10] can be improved by:

(a). Incorporating ***conditional clauses*** which state what to do under circumstances different from those originally envisioned in the recommendation. These deviations could be attributable to the farmer, weather conditions, lack of availability of some of the technological components, etc. Included in the conditional clauses are possible variations such as: a recommended step-wise approach to the adoption of the different components of the package, and suggesting a number of options for the farmer to pursue.

(b). Including ***targeting information*** showing under what technical and socio-economic conditions the technology being recommended would be most applicable. For example, a particular technology may be most suitable for one soil type, or for farmers with a specific resource base. For instance, double plowing is most appropriate on soils that are reasonably deep and have a fairly high clay fraction, while the rotary injection planter is most suitable for farmers who do not have good control over draft power.

Thus in recognizing the diversity of farmers, on-farm research can help in developing targeted and conditional clauses for proposed improved technologies. In doing so, it can potentially improve the return from the limited research resources by providing a technology which is appropriate to more farmers through widening intervention possibilities. It is particularly important to develop a range of options when dealing with a difficult farming environment such as exists in Botswana. In a sense, these guidelines indicate how greater numbers of farmers can more closely approach the optimal situation.

5.5.4 ACCEPTABLE INFORMATION FOR FORMULATING RECOMMENDATIONS

Often information required for approving recommendations has consisted of hard objective data collected in an RMRI experimental environment. However, as was indicated earlier, there is an increasing acceptance of the need to conduct a socio-economic evaluation, as well as the more common technical analysis. We have found that, in order to more closely approach the farmers' operational environment, much of the data required are best collected in an RMFI experimental environment. However, as was discussed earlier (Section 2.4.2), there is likely to be a corresponding increase in the softness of the data -- therefore potentially reducing its acceptability in the technology evaluation process. Increasing amounts of qualitative attitudinal data, collected at the FMFI level, are likely to be even more suspect in such an evaluation exercise. As has been emphasized earlier, it is unfortunate that a move towards greater incorporation of the farmer -- the ultimate customer of trial work -- in the evaluation process, has a tendency to result in a more qualitative/softer type of data, that is generally less acceptable in approving official recommendations. There is obviously no easy solution to this problem, but we believe that a judicious mix of hard/quantitative and soft/qualitative data may be useful in the evaluation process.

[10]. See also discussion by Byerlee [1986] on prescriptive and auxiliary information.

Scientific objectivity, requiring many years of painstaking experimental work -- often in a somewhat artificial environment -- should not, we believe, be completely substituted for researcher judgement. For example, we believe that some of the information needed for drawing up the conditional clauses and targeting information which were discussed in the preceding section, does not require exhaustive experimentation, but can be derived from the knowledge and experiences of trained scientists working at the farm level. Resources for research are limited, and ways need to be sought to maximize the return from them so as to facilitate the agricultural development process.

On-station researchers are understandably careful about making recommendations,[11] while extension staff are, also justifiably, anxious that recommendations are forthcoming on a regular basis. Since farming systems researchers work with relatively few farmers, it is important that the recommendations they make are formulated and passed on to extension at the earliest possible opportunity, in order to maximize their impact on the farming population. Although it is desirable to defer making recommendations until there has been some adoption, for reasons discussed earlier, this often results in unacceptable time delays. Rather, recommendations need to be based largely on ex ante evaluation. Because of limited research resources and diverse interests of groups using research results, we would like to see a move toward devising interim best-bet recommendations, based on the best knowledge currently available to the research scientists.[12] These should have the proviso that they can be modified in the light of further research. There is, of course, an inherent danger in doing this especially if an interim recommendation has any possibility of adversely affecting the environment or farmers' welfare. However, if the relevant interested parties are brought together, it should be possible to avoid drawing up inappropriate recommendations. This is one of the reasons why there is a role for a Recommendations Committee at the headquarter level.

5.6 USEFUL REFERENCES

Section 5.1:

Caldwell and Walecka, 1987: pp. 1-18.
Shaner, Philipp and Schmehl: 1982, pp. 87-107, 111-122.

Section 5.2:

Caldwell and Walecka, 1987: pp. 51-58, 61-68, 73-80, 107-110, 118-131, 139-237.

Section 5.3:

Amir and Knipscheer, 1989: pp. 103-112.
Bernsten, Fitzhugh and Knipscheer, 1984.

[11]. Optimum recommendations, drawn up after many years of work on the experiment station will, in fact, given the heterogeneity within the farmers' environment, not be optimal for most farmers.

[12]. In a sense, this idea is included in the leaflets entitled ***Guidelines to Promising Technologies***, mentioned earlier, which are being produced to stimulate more widespread testing of proposed technologies.

Caldwell and Walecka, 1987: pp. 256-259.
Zandstra, 1985.

Section 5.4:

Caldwell and Walecka, 1987: pp. 19-35.
Shaner, Philipp and Schmehl, 1982: pp. 139, 142-143.

Section 5.5:

Byerlee, 1986.
Norman, 1989B.
Norman and Modiakgotla, 1990.

PART THREE:

IMPLEMENTATION PROCEDURES

CHAPTER 6: GENERAL MANAGEMENT ISSUES

6.1 SELECTING VILLAGES AND FARMERS

This section discusses the approach taken by ATIP in selecting villages and farmers to participate in various surveys and field trials. The approach taken by both the Mahalapye and Francistown teams was basically the same.[1]

6.1.1 SELECTING TARGET AND RESEARCH AREAS

The target area for the ATIP project was defined by the Government of Botswana as the eastern part of the country, particularly the central and northern portions. Within that general area, the Ministry of Agriculture specified that one ATIP team should be located in the Central District at Serowe, Palapye, or Mahalapye, and one team should operate in the Tutume Agricultural District. Mahalapye was chosen by the ATIP staff, in consultation with the Director of Agricultural Research and USAID, because of the existence of an experiment station at that location, and for logistical reasons. In terms of sub-research areas, the Francistown team was assigned the Tutume Agricultural District for its responsibility. The Mahalapye team chose to begin work in the Mahalapye West and Mahalapye East Districts, with plans to add an additional village in the Palapye District at a later date. After the extension areas were chosen within which research was to take place, villages had to be selected.

6.1.2 SELECTING RESEARCH VILLAGES

We took two basic steps in selecting research villages. The first step was to identify agricultural practices, the environmental setting and resource endowments of households within the research areas. This information was collected from secondary sources, from discussions with knowledgeable people -- including regional and district agricultural officers, village leaders and farmers -- and from personal observation by team members. In one case, the ATIP team used an exploratory survey form (see, for example, Form A1.1 in Annex Volume [Worman, Norman and Ware-Snyder, 1990]) as a guideline in conducting informal interviews in a number of villages which were likely research villages (based on criteria such as having a resident AD). In the case of the other team, the villages were selected on the basis of representing predominant traction patterns (cattle and tractor in one case, and donkey in the other). In this instance, a similar exploratory survey was conducted, after the villages were chosen, in order to establish a research focus and to define research domains [Baker, 1987: p. 25]. In both cases, villages were selected to represent a diversity of conditions within the respective agricultural districts. In addition to predominant traction type, other factors considered were the social organization of the community (i.e., whether it had traders, an active community organization in terms of building schools and other community infrastructure, etc.), and its location relative to major commercial centers. Logistical considerations (e.g., accessibility during the rainy season) were also important in determining the location of villages, while the availability of staff determined the number of villages where research could be carried out.

[1] Material for this section was taken from ATIP [1983: pp. V13-V17], Baker [1987; pp. 24-27], and Miller [1983].

6.1.3 SELECTING REPRESENTATIVE HOUSEHOLDS

Based on a literature review, discussions with knowledgeable individuals, and exploratory surveys, recommendation domains were defined. In one case, the major criterion used was the ability to implement timely planting and multiple tillage operations. The factor used to define recommendation domains in this case was the control of draft. Two domains were identified, those who owned, managed or borrowed draft, and those who hired or shared draft. In the other case, resource endowments were considered the major factor in defining recommendation domains, and the number of cattle owned was used as a proxy for resource endowments.

Secondary factors, used to define sub-domains included:

(a). Sex of head of household,
(b). Different types of draft power: tractor, cattle and donkeys, and
(c). Use of broadcast or row planting.

Other factors were also considered, such as smallstock ownership, presence of wage earners in the family, etc.

In order to select a group of representative farmers to participate in on-farm trials or various types of studies, we had to create a list of all (or most) households containing information about the households. To devise this type of list, we conducted a Census Frame Survey (Form A1.2 in the Annex Volume [Worman, Norman and Ware-Snyder, 1990]). When conducting a Census Frame Survey, in addition to asking technical questions about household resources and agricultural practices, it is important to determine if the household members are willing to cooperate with the research program.

The number of households in each stratum of the recommendation domains generally depends on the relative proportion of households in the overall population (as determined by the Census Frame Survey) which possess the desired characteristics. We created a matrix of cells composed of major and minor characteristics of importance. The number of households included in each cell was based on the percentage of the total population in that cell category. Households were then chosen according to the cell to which they belonged. Additional interviews were conducted to assure willingness to cooperate. In some situations, other factors involving logistics were considered. For example, in one case, households were clustered to reduce enumerator travel time. In another case, households were chosen within 10 kilometers of the village to reduce travel problems.

A Census Frame Survey can serve as a list for selecting farmers for a number of different surveys or activities. After a number of years -- most likely between five to ten years -- depending on the amount of change in the population, such a list will no longer be valid and a new census must be undertaken, or some other method sought to update the list of households.

6.2 TRAINING FIELD STAFF

6.2.1 INTRODUCTION

If a farming systems team is to function effectively, all field staff (technical officers, enumerators, and field assistants who live and work in a specific village) will require some

type of formal training throughout a given research season. Although their roles in the research effort may not be as technical as the research officers, the field staffs' impact on the quality of work researchers are capable of performing cannot be discounted. Field staff are responsible for the accuracy of data collected through trials, studies, and surveys. They also are an important link between the researchers and the farmers. In a sense, the level of field staff skills in collecting data and liaising with farmers define the boundaries within which a research effort will succeed or fail.

The primary purpose of training field staff, and indeed of having field staff, is to collect good quality research data. The better the quality of data, the better is the quality of the research which the team produces. This section discusses field staff training and ways of collecting good quality data.

6.2.2 IN WHAT AREAS DO FIELD STAFF NEED TRAINING?

Field staff need continuous training in conducting trials, studies, and surveys. They may also need occasional training in other areas, such as time-management, personal organization, how to conduct individual farmer visitations, and how to lead farmer group meetings. An important component of this training process consists of frequent visits by research supervisors to check on field staff activities, and to review data collection forms for problems.

6.2.2.1 Trials Work

Generally, field staff need training in seven areas of trials work. They need to know:

(a). Objectives of and justifications for proposed trials, including a brief summary of the previous season's results which have a bearing on the current season's trials.

(b). Experimental designs of each trial (i.e., layout of trial plots; number of locations, farmers, and replications; and types and numbers of treatments and factors). In the case of trial factors, such as fertilizer levels, the various factor levels should also be discussed.

(c). Equipment and materials needed for trials' implementation (i.e., quantities of seed and fertilizer per site; number and type of implements per trial; and number and types of plot pegs per site).

(d). Rationale for trial formats (RMRI, RMFI, and FMFI). See Section 2.4 for further information on trial classification.

(e). Layout of data collection forms -- why, how, and when to record data.

(f). Other materials needed to collect data (i.e., scales, quadrats, tape measures, knives, etc.).

(g). Time-frame for trials' implementation (i.e., when and how trials should be introduced to farmers, and how equipment and materials will be distributed).

6.2.2.2 Studies And Surveys

Training requirements for studies and surveys are similar to those for trials' work. They include four general areas:

(a). Objectives of and justification for proposed studies/surveys, including a brief summary of the previous season's findings.

(b). Layout of study and/or survey forms -- how and when to record study requirements and/or farmer responses.

(c). Data collection equipment and materials needed.

(d). Time-frame for studies/surveys implementation (i.e., which farmers should be surveyed; what will be studied; when the studies/surveys should be conducted; and when the surveys should be completed).

6.2.2.3 Other Areas Where Training May be Required

Depending on research time constraints, field staff skill levels, and field staff desires, other areas where training might make a positive impact on the research effort include:

(a). Time management
(b). Personal organization
(c). Conducting individual farmer visitations
(d). Leading farmer group meetings

This is not an exhaustive list. As research progresses, researchers might identify several additional areas where field staff, and consequently the entire research effort, will benefit from formal training. In some instances outside support -- either directly or indirectly -- can be enlisted from experts in a given area. For example, a sociologist/anthropologist can give a workshop to field staff on interview methods.

6.2.3 WHY TRAIN FIELD STAFF?

There are six primary reasons why field staff need training:

(a). Training helps in informing field staff what the data will be used for and emphasizes the significant role they play in collecting that data.

(b). Training encourages more open communications between researchers and field staff, which in turn leads to enhanced cooperation.

(c). Training provides an additional opportunity for research officers to assess the quality of proposed trials, studies, and/or surveys.

(d). Training helps ensure good quality data by minimizing measurement errors associated with trials, studies, and surveys.

(e). Training enhances the field staffs' career potentials (both academically and non-academically). Perhaps most importantly, a formal training session demonstrates the

research officer's commitment to enhancing the field staffs' career potentials.

(f). Training provides an opportunity for field staff input into the experimental-design process, rather than restricting the field staff to simply asking questions and collecting data for the researcher. During the course of training, field staff might identify infeasible components of a trial, study or survey.

6.2.4 METHODS FOR TRAINING FIELD STAFF

There are two common methods of training field staff -- group training sessions at the main team office and individual consultations in the field. The most effective training strategy is to combine both methods, using each as needed during the research season.

6.2.4.1 Group Training Sessions

Group training sessions can be held when appropriate. For example, one is usually held at the beginning of the cropping season to provide instruction on the season's activities. Training sessions are enhanced through the use of visual aids, such as slides, posters, and overhead projections, but only when appropriate. The sessions should be scheduled as conveniently as possible for field staff -- in terms of dates, venue, and accommodations.

Group training sessions at the team's main office have the following advantages:

(a). Assuming logistical constraints are not numerous, training sessions can save researcher time and resources.
(b). Training sessions allow for group interaction -- a process which usually encourages brain storming and leads to more effective results.
(c). Training sessions are more "official". Field staff are likely to view such formal group training favorably.

On the other hand, group training at the FSR teams' main office may have the following disadvantages:

(a). Assuming logistical constraints are numerous, training sessions can waste researcher time and resources.
(b). By having to travel away from their research villages, group training sessions can waste field staff time and resources.
(c). Field staff, who are inhibited by group discussion, may not contribute during the training session.
(d). Training sessions can become a "crutch" for researchers when they replace necessary field follow-up and individual training sessions.

6.2.4.2 Individual Consultations In The Field

Individual consultations with the field staff in the field are always necessary throughout the year. These sessions only require mobility on the part of the researcher, and are useful in discussing problems about trials, studies, and/or surveys.

Individual consultations in the field offer the following advantages:

(a). They provide an opportunity to review data collection forms (field record forms and survey forms) and to give additional specific training, as necessary, to resolve problems.

(b). Individual consultations enable the researcher to concentrate on each individual in the field team, thereby highlighting potential problems on an individual basis before they adversely affect the research effort.

(c). Individual consultations allow those inhibited by the group process a chance to express their opinions.

The disadvantage of such consultations is that if done excessively, they are considered less "official", and field staff may not be as interested nor inspired during the training process.

A combination of group training sessions and individual consultations is necessary during most seasons. By using both methods, researchers attain the best of both forms of training. Group training cross-checks individual consultations and vice-versa.

6.2.5 WHAT IS "GOOD QUALITY DATA"?

Good quality data are data that meets the particular needs of the trial, survey or study being undertaken. How accurate the data need to be is related to what use will be made of the data. Not all data must be collected with a high degree of precision. If the data will be used in a way which requires only a low degree of precision (i.e., a rough estimate), then the data should not be collected in great detail. Generally speaking the greater the accuracy of the data needed, the higher the cost in terms of personnel time and other resources needed to collect it. Thus it is important for researchers to decide the degree of accuracy required and collect accordingly. This will then produce good quality data for that particular activity.

Good quality data accurately reflects past and/or current activities, enterprises and environments. When predictions are to be made, it is particularly important that the data accurately reflect the actual situation. By "accurate" we mean unbiased. Biased data often results from improper sampling and/or poorly-trained field staff. Therefore, good quality (or accurate) data are contingent on the sampling procedure and the competence level of the field staff.

It is important that data be unbiased so that subsequent statistical analyses can be used to accurately document a given situation or provide a base on which to make predictions. The following suggestions will aid in collecting unbiased data.

6.2.6 WAYS TO IMPROVE ACCURACY OF DATA

In order to ensure the collection of good quality data, the following guidelines are recommended:

(a). Measurement error should be lowered to an acceptable level commensurate with the design of the trial, study, or survey and the resources available to collect the data. It is important to remember that measurement error can never be completely eliminated. No matter who gathers data, there will always be room for error. Yet, measurement error can be minimized by using proper measuring instruments, and by training data

gatherers in the proper measurement procedures.

(b). Sampling error should also be reduced to an acceptable level. Sampling error can be reduced if the sampling frame adequately reflects the whole population, and if appropriate sampling procedures are used to draw the sample.

(c). The experimental design for each trial, study, and survey will depend on the purpose of the trial. Each type of trial has particular types of data which are relevant and realistically obtainable. Experimental design concerns the types of variables being measured, such as yield, rainfall, labor times, etc., and the factors which are included in the trial or study in order to influence the variables (e.g., fertilizer levels). The researcher must always bear in mind constraints which might make collection of some data impractical.

(d). Field staff biases can be reduced through a good training program.

(e). Relevant secondary data may be used to augment primary data (i.e., data collected in the field by the researcher). Secondary data are typically compared with primary data in order to widen the interpretation of on-farm research results. For instance, mean yields from a trial might be compared with mean regional or district yields reported in Agricultural Statistics for that season. Such comparisons enhance the usefulness of the more localized data obtained from a trial implemented in a few villages.

(g). In the case of studies and surveys, survey forms should be pre-tested. Pre-testing often demonstrates the inappropriateness of certain questions, and pinpoints where modifications to the survey form can be made, thus enhancing the study's or survey's overall effectiveness.

(h). In the case of trials, farmers working in a group format are often encouraged to implement trials more accurately and completely because of the peer pressure exerted during group meetings.

(i). Good logistical support should be institutionalized -- see Section 6.4 for more information on arranging logistical support.

6.3 INTERACTING WITH FARMERS

6.3.1 INTRODUCTION

Interactions between research and extension personnel and farmers can sometimes be poor because of shyness, a lack of respect for, or not knowing how to communicate with the farmers.

In order to improve the quality of such interaction it is important for research and extension staff to accent the following:[2]

(a). They should respect the farmers, for their knowledge they have and the hard work they do.

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[2]. See also Section 3.1.2 for an analogous discussion on approaching the farmer.

(b). They should realize that they are there to serve the farmers, not the other way around.

(c). They must understand that the farmers are not there only to do trials and demonstrations. They have other important objectives, like working to feed their families. Therefore farmers cannot always put give high priority to trials and/or demonstrations.

(d). Sometimes research and extension staff feel they must give answers to all questions, whether they are sure of their facts or not. Instead, they should realize that giving wrong information to farmers is much worse than saying "I don't know" because eventually they will lose the farmer's confidence. In this case it is best to answer: "I don't know, but I will find out". They can also check with other farmers to see if they have any good solutions.

(e). The concept of the trial and procedures must be explained fully and carefully, several times, especially where farmers are conducting experiments for the first time, since they often have difficulty understanding the concept of "comparisons".

(f). Since no technology works in all places, at all times, it is dangerous to tell farmers "this works", "this doesn't work". Instead it is better to say, "in our experience, this works more often than that", then suggest the farmers try it, and form their own opinions.

(g). It is also important to be well prepared. Farmers lose confidence when they come to a demonstration and the equipment doesn't work, or they are promised seed and it is not delivered. Officers should prepare thoroughly, in advance, before meeting farmers, and work hard to fulfill their promises.

(h). It is important to listen to and, where possible, desirable or relevant, attend to farmers' problems quickly.

Farmers' participation is critically important in FSR. The level and degree of participation of course varies according to the nature of the trial (Tables 2.1 and 3.1) or survey. In RMRI trials, the farmer provides the land and the researcher provides all the inputs and controls the trial. The farmers' contribution is in a sense minimal. On the other hand in RMFI trials the farmers' participation is much greater, since they are responsible for implementing the trial under the management of the researcher. Thus in this type of trial the quality of the interaction becomes critically important. Finally, in FMFI trials the farmer is in complete charge and the researcher is dependent on good interaction in order to reap any benefits from the trials.

Although the intensity of interaction with the farmer will depend on the type of trial, there are a number of factors that will influence the nature of the relationship. These are discussed below for each type of trial. Researcher-farmer relations, location of trials on the farm, on-farm trial designs, field data management, and standardization are a few things that need to be considered when conducting research in farmers' fields with their active participation.

6.3.2 RMRI TRIALS

Relevant points with reference to RMRI trials are as follows:

(a). ***Selection Of Farmers.*** In this type of trial, the selection of farmers depends less on their resources -- since these are provided by research -- and more on the technical environment (e.g., are soils representative for the area?). Nevertheless, having said that, a significant secondary criterion in the selection process is the interest and potential for cooperation individual farmers have shown. Also of course they need to possess a large enough area of suitable land to allocate to a replicated trial. Each farmer is approached individually. Researchers meet the farmer before the planting season to discuss the proposed trial, and to find out if the farmer is willing to host such a trial. The farmer is encouraged to take an interest in the implementation of the trial and, to the extent possible, to comment on and evaluate the results.[3] The more the farmer understands about what is going on, the more capable he/she will be in explaining it to visitors and friends, so that more individuals can learn from the trial.

(b). ***Site Selection.*** The site should be representative of the target environment and should include the type of soil and topography suitable for research work. It is important to make clear to the farmer that such conditions are needed to prevent bias in the results. A trial site should not be located where there are paths, ditches, large trees and other conditions which are not normally part of the environment. To ensure good researcher-farmer relations, it is very important that the site be satisfactory for both the farmer and the researcher.

(c). ***Implementation.*** Farmers must understand the importance of the trial to the researchers. The risk of not completing on-farm trials is higher than with experimental station trials. All the arrangements and the implementation is carried out by the researcher, but the farmer, as a partner, should be informed of the whole procedure so that he/she will not destroy it through independent action, or by accident. Although all the work is carried out by the researcher or under the researcher's supervision, members of the host family can participate when invited, or when they have time, and are interested to learn more about the technology. The farmer can also be hired to do some of the work, for example, weeding, bird scaring, threshing, and may provide the draft power. The farmer is paid for this work, and in most cases, the grain yields are given to the farmer in lieu of rent.

(d). ***Data Collection.*** Information recorded in on-farm trials is usually less than in trials conducted on experiment stations. Researchers should not collect data beyond what is appropriate for the area and the trial. Farmers develop high expectations when something is done on their farms, and their curiosity should be satisfied as quickly as possible if their support and assistance are to continue. Consequently it is important to ensure that as little time as possible lapses between the completion of trials (recording data) and informing the farmer of the results.

(e). ***Yield Estimation And Result Assessment.*** For most trials this is the final stage of assessing and evaluating a given technology, with yields from the different plots representing the differences between treatments. A suggested procedure is as follows:

i. It is important to inform the farmers that production obtained from the trial will eventually be theirs to keep. One approach is to leave all the grain at the farmer's house for drying, threshing and weighing. However, sometimes

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[3]. An informal grouping of farmers has also been used to provide such inputs in the Mahalapye area (see footnote "a" in Table 3.1).

this is not possible if detailed information is required on seed weight, seed number, etc.

ii. Farmers should be given the opportunity to see the yield differences that occurred between the plots before the grain is combined for storage. This provides them with an opportunity to appreciate the treatment differences attained.

iii. After harvest estimation is completed, farmers should be thanked for their assistance, and plans for the coming year discussed with them. For example, whether the same trial will be repeated, what modifications will be made, whether the same or a different location should be used, etc.

6.3.3 RMFI TRIALS

Relevant points with reference to RMFI trials are as follows:

(a). ***Selection Of Farmers.*** Farmers for these trials are selected in the same way as in RMRI trials. They are contacted individually before the beginning of the planting season. Since in RMFI trials farmers carry out the work under the guidance of the researcher, it is extremely important that the farmer understands the differences between the treatments, what is being compared, what is required for the different treatments, and appreciates the importance of proper experimental procedures. It is also essential that the farmer has a genuine interest in the trial so that he/she is serious about properly implementing the procedures. The farmer must also have the necessary resources to conduct the trial. Proper selection of farmers in this case requires a good deal of researcher-farmer discussion. Proper selection of participating farmers can make all the difference between successful and unsuccessful RMFI trials.

(b). ***Site Selection.*** As with RMRI trials, a representative location should be chosen for the trial so that the results can be generalized. Portions of the field with big trees or stumps, paths, ant hills and ditches should be avoided. Again, the location must be mutually agreed upon by both parties.

(c). ***Implementation.*** When conducting RMFI trials, the researcher must appreciate that the farmer is not simply someone to be given instructions on what to do. Rather, the farmer is someone who is responsible for many different activities. What the researcher wants creates additional responsibilities for the farmer. Therefore the work that the farmer is to do must be discussed and mutually agreed upon. Researchers must accommodate the other priorities of the farmer within the experimental design. Thus, although the farmer does all the implementation under the guidance of the researcher, there is a sharing of responsibilities and the farmer plays a significant role so that he/she can be in a position to assess the potential value of the technology under practical farming conditions.

(d). ***Data Collection.*** The farmer should be informed during the planning of the trial what data will be collected. Before the trial work begins, it is important to decide on how to record the data collected. It is advisable to develop some standard procedures on how to collect the data. These procedures will help to protect the reliability of the information and will help to speed up the data processing and analysis.

(e). ***Yield Estimation And Result Assessment.*** It is important that the farmer understands the harvest procedures and that he/she is to compare the yields of the different plots. It is usually necessary, every year, to remind the farmers about this before harvest time, and to check the procedures during and after harvest. Generally the farmer will assess the value of the different treatments, not only in terms of yields, but also in terms of the inputs required to obtain those yields. In this type of trial, both farmer assessment and researcher judgement -- based on documented figures -- are used in the final assessment of the different treatments.

6.3.4 FMFI TRIALS

Most of the FMFI trials are undertaken through farmer groups (see Section 13.1). The object is to test a broad range of technologies under a wide range of conditions. As well as helping to determine what types of innovations are most appealing to farmers with a wide range of resource conditions, they provide a good way of estimating the robustness of different technologies under real farm conditions Additionally FMFI trials provide an opportunity for involving farmers directly in the technology generation and assessment process. Points to note are as follows:

(a). ***Selection Of Farmers.*** Prior to the onset of the rains at the beginning of the cropping season, research staff attend a village **kgotla** meeting at which they make a formal report describing the results of the previous year's research. They also describe the plans for farmer group activities for the coming year, and invite anyone wishing to participate in the farmer group to attend the first group meeting.

At the first group meeting, a wide range of technology options are discussed. Farmers are then asked to select any innovation or package of innovations they wish to test. They are also invited to add any items, which have not been mentioned, to the list. Those farmers wanting to undertake a trial form the farmer group that meets on a regular basis.[4] AD's are also invited to attend these meetings, where progress and problems are discussed.

Examples of the types of technologies that have been tested by farmers in these groups are:

i. Tillage/water conservation techniques
ii. Planting methods options
iii. Crop varieties
iv. Manure and fertilizer options
v. Forage and fodder production options
vi. Evaluation of implements
vii. Seed protection options

(b). ***Site Selection.*** Farmers themselves choose the sites for their trials. However, they are asked to site them where the test and control plots are as similar as possible.

(c) ***Implementation.*** After the first group meetings, discussions about the trial procedures are repeated in later meetings. Additionally, where necessary, village staff visit farmers to assist in the implementation. Items that are to be tested are supplied to the individuals in the groups. Any equipment being tested is given out on a loan

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[4]. They meet monthly in the Francistown area and less frequently in the Mahalapye area.

basis. After selecting the technologies they would like to test, farmers cut pegs for marking the plots. ATIP field staff visit each farmer to help in pegging each trial and to make sure that the farmers understand what they are supposed to do in terms of implementing each trial. Staff may help supervise implementation, particularly in the case of unfamiliar equipment.

Field days are often held in each village. At these field days, a selection of the participating farmers are given the opportunity to explain and show their trials to the rest of the group, as well as to farmers from outside the group, and to research and extension staff.

(d). ***Data Collection.*** Because of the FMFI format of the trials, particular emphasis is given to obtaining farmer opinions rather than on gathering much quantitative data. The farmers assess the technologies and discuss them during the regular meetings. As a result, the farmers provide feedback on problems raised, and where possible help find alternatives or solutions to them.

(e). ***Yield Estimation And Result Assessment.*** At the end of the season the farmers harvest the plots separately to compare the yields, and are helped by the field staff to weigh the produce. As in other types of trials, the farmers are allowed to keep any production from the testing work they conduct. Implements are assessed only by conducting an End-of-Season Survey through which farmers express their views on the particular item they have tested. All other trials are assessed by yield comparisons and End-of-Season Surveys.

6.4 ORGANIZING LOGISTICAL SUPPORT

Logistical support relates to issues of mobility, work circumstances and support staff which can either assist greatly or adversely influence the most effective deployment of both physical and human resources during agricultural research. It should be noted that logistical needs can be determined and influenced by the characteristics of a particular location, the types of surveys, studies or trials, and the personalities of the individual researchers.

6.4.1 GENERAL ORGANIZATIONAL ISSUES

For smooth implementation of trials and surveys at the farm level, some of the major points that need to be attended to are the following:

(a). ***Careful Planning.*** It is important to ensure that the number of research topics pursued does not exceed the resources available to successfully conduct the research. Over commitment may lead to mismanagement or neglect of some trials, studies or surveys. The work plan should be drawn up by the FSR team as a whole, and implemented after being discussed with senior extension staff in the region, and going through the approval system operating at DAR headquarters (see Section 1.3.3).

(b). ***Adequate Manpower Deployment.*** To ensure the proper implementation and monitoring of trials, it is important that the personnel are competent and skilled at their jobs. Generally, at least one person at certificate level is needed to live in each study village. Other field staff who are employed to record data should have at least a Junior Certificate level of education.

(c). ***Clear Understanding By All Parties.*** It is essential that the participating farmers, FSR field staff, and local extension staff, all have a clear understanding of the trial, study or survey objectives, how to implement them, and how to collect and record the necessary data. With respect to this, in-service training programs are particularly important for field level staff. Also all parties need to agree and know well in advance what they are expected to contribute to the overall effort in implementation of the trial, study or survey.

(d). ***Ensuring Efficient Day-to-Day Communication.*** Two-way radios, though expensive, are a very important and efficient way of clarifying and solving logistical issues which do not need the physical presence of the researcher. Also these radios enable researchers to be promptly notified of any rainfall which, in turn, can influence the timing of operations in the researcher managed trials.

(e). ***Day-To-Day Supervision.*** To ensure that planning, implementation, and data recording of trials, studies and surveys are undertaken satisfactorily, research staff should make regular visits to the field and check implementation progress and data collection forms for inaccuracies and inconsistencies. Some of this supervisory work can, on occasion, be done by one or two senior level field staff who generally have a certificate level qualification, and who operate out of the regional FSR office.

(f). ***Guaranteed Mobility.*** It is essential that an efficient means of transport is provided for personnel monitoring the trials and collecting the data. Providing bicycles to all field staff has been found to be the most effective and cheapest way of ensuring mobility at the village level. At the regional FSR office a viable vehicle policy also needs to be established and agreement reached among FSR staff on the efficient use of the vehicles in trips to villages. Having someone to coordinate the use and the servicing of vehicles at the regional FSR office has proved to be helpful.

(g). ***Adequate Supplies And Equipment.*** Such items as spare parts for the bicycles, measuring tapes, scales, quadrats, notebooks, pens and pencils, etc., are necessary for day-to-day operations. By virtue of their importance, these items should always be in store, or money must be readily available for their purchase, as needed.

(h). ***Data Collection, Processing, Analysis Link.*** In order to ensure rapid turnaround from collecting data to producing tabulated results, the following actions must be undertaken:

i. The data collection forms need to be set up so that the data can be directly transferred to the microcomputer (see Section 7.3.4(k)).

ii. Microcomputers plus secretarial staff trained in their use are needed at the regional FSR office.

iii. Secretarial staff at the regional FSR office should take primary responsibility for entering data on the microcomputers. A discussion on suitable software is given later in the handbook (see Section 10.6).

iv. Research staff at the regional FSR office should be responsible for ensuring that the data have been entered correctly, and for analyzing and writing-up the results. Once again Section 10.6 should be consulted for a discussion on suitable software.

6.4.2 SPECIAL LOGISTICAL SUPPORT ISSUES FOR DIFFERENT TYPES OF TRIALS

In addition to the general logistical issues raised above, there are a number of issues that apply to the different trial formats. Some of the major ones are discussed below:[5]

6.4.2.1 RMRI Trials

Points to bear in mind are the following:

(a). Selection of farmers to participate in the trial is based on the requirements of the trial (e.g., whether draft power is necessary, soil type required, etc.).

(b). It is important to establish a "contract" with the farmer before the rains start. Because some of these trials may be long-term, requiring more than one season's investigation on the same plot location, both the farmer and the researcher must have a clear understanding of the probable duration of the trial.

(c). The materials to be used in the trials (e.g., seed, fertilizer, etc.) must be accurately measured by FSR staff, and be applied by the researchers and not the farmer.

(d). All management and implementation activities are undertaken under the direct supervision of research personnel.

(e). For monitoring purposes, it is necessary for the researcher to visit the trial on a weekly basis.

6.4.2.2 RMFI Trials

Specific points are the following:

(a). The FSR staff must select participating farmers according to the trial requirements.

(b). Before the onset of rains, an agreement -- regarding trial location within the farm, duration and plot size -- must be reached with the farmer.

(c). The materials to be used in the trial (e.g., seed, fertilizer, etc.) must be accurately measured by FSR staff and given to the farmer for use at the appropriate time.

(d). Trial implementation (e.g., planting) should be conducted according to trial design, and should normally be undertaken with FSR staff being present. FSR staff provide the managerial input and the farmer does the work.

(e). Samples of the harvest should be weighed and used by FSR staff for estimating yields.

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[5]. Because of the issues involved there is a certain amount of repetition, since some of the points are discussed elsewhere in the handbook (see especially Section 6.3).

6.4.2.3 FMFI Trials

As has been previously discussed in the handbook (see Section 13.1), farmer groups are frequently used by ATIP in testing technologies at the FMFI level. One of the major reasons for using this approach is that it is an efficient way of using researcher time and providing logistical support.

Anyone is allowed to join the group as the result of an invitation given at the **kgotla** meeting. Arrangements are made for the groups to meet at the beginning of the rainy season and at regular times during the year. At the initial meetings, field and research staff should:

(a). Discuss the previous year's trial results.
(b). Fully explain what technology options are available for the current year.
(c). Permit farmers to freely decide on which options they would like to test.
(d). Distribute available material -- for each chosen technology option -- to the farmers.

Once the technology to be tested has been selected, and before planting has begun, the field staff should help farmers mark/peg the plots, and record the necessary information on the data forms.

During the trial, all management practices should be left to the farmer (i.e., weeding, bird scaring, harvesting and threshing). However, the field staff should make sure that the farmer understands the required harvesting procedure, and they should weigh the produce after threshing. Additionally, FSR personnel should make periodic visits to the farm/trial to monitor progress.

6.4.3 LOGISTICAL ISSUES AT THE REGIONAL FSR OFFICE

Before commencing any research, the trial objectives, experimental design, plot layout, and data collecting forms, for each trial, must be well defined and understood.

Logistical support issues include the following:

(a). It is important to ensure that the materials to be utilized in each trial are in adequate supply and properly measured.

(b). A joint workplan should be devised with the cooperation of all team members and/or researchers.

(c). A viable vehicle policy should be formulated. Project and/or Government vehicles should be made available to station-based researchers at all times to allow for periodic/frequent field visits.

(d). Data obtained from the trials should be conveyed, as quickly as possible, to all parties involved so that they stay well informed of any new developments.

(e). The regional FSR team should include one or two members with certificate level education who are responsible for coordinating research activities within the villages.

6.5 USEFUL REFERENCES

Section 6.1:

ATIP, 1983: pp. V12-V17.
Miller, 1983.

Section 6.2:

Andrew and Hildebrand, 1982: p. 56.
Caldwell and Walecka, 1987: pp. 340-342.
Mutsaers, Fisher, Vogel and Palada, 1986: pp. 140-141.
Shaner, Philipp and Schmehl: 1982: pp. 306-316.

Section 6.3:

Caldwell and Walecka, 1987: pp. 240-246, 345-354.

CHAPTER 7: SURVEYS

7.1 TYPES OF SURVEYS

In Section 2.5 we discussed the different methods used for collecting data. We indicated a number of factors that influence the method of data collection to be used. When these were evaluated in terms of operational constraints (Table 2.2), we showed that surveys are a very useful and efficient means of collecting data. We also outlined the different types of surveys that can be undertaken (Figure 2.3). A major breakdown was in terms of:

(a). Informal or unstructured surveys.
(b). Formal structured surveys.

In Sections 7.2 and 7.3 these two types of surveys are examined in more detail, noting their respective value and issues concerned with their implementation. However, Table 7.1 presents, in general terms, some of the distinguishing characteristics of these surveys. These characteristics highlight the different uses and means of implementing these surveys.

TABLE 7.1: COMPARING GENERAL CHARACTERISTICS OF FORMAL AND INFORMAL SURVEYS

CHARACTERISTIC	INFORMAL	FORMAL
Background information required	Minimal	Substantial
Time allocation by researchers:		
Preparation	Less	More
Implementation	More	Less
Analysis/writing up	Less	More
Total time	Less	More
Hypotheses: Required beforehand	Not essential	Essential
Created during	Yes	No
Likely discipline interaction	More likely	Less likely
Implementation:		
Questionnaire used?	No	Yes
Interviewers	Researcher(s)	Mainly enumerators
Potential for creativity/iteration	Maximum	Minimal
Potential for learning/verification	Mainly learning	Mainly verification
Potential for representative sample	Less likely	More likely
Potential quality of information:		
Attitudinal	Better	Poorer
Qualitative	Better	Poorer
Quantitative	Poorer	Better
Probability of high: Sampling errors	Higher	Lower
Measurement errors	No difference	No difference
Value of statistical techniques in analysis	Little	Great

7.2 INFORMAL SURVEYS

7.2.1 FEATURES OF INFORMAL SURVEYS

Other names for informal surveys that are found in the literature are **sondeos**, rapid

reconnaissance surveys, and exploratory surveys. In recent years the evolving methodology for these types of surveys has become more generally recognized and known as rapid rural appraisal[1]. All informal surveys have five distinguishing characteristics which are illustrated in Table 7.1:

(a). There is direct researcher-farmer interaction since the interviews are conducted by the researchers themselves. Existing information and direct observation are also important sources of information in an informal survey.

(b). Interviews are basically unstructured and semi-directed. Questionnaires are not used, although often researchers use topic guidelines to make sure all relevant topics, on a given subject are covered. Sometimes written notes are taken during the interviews, the emphasis being on dialogue and questioning to provide information.

(c). The data collection process is dynamic and iterative because researchers evaluate the data collected, and reformulate data needs on a daily basis. Interviews often first cover the broad characteristics of the farming system, and later focus on priority problems, potential solutions, and the interactions of these with aspects of the system.

(d). The interviews are conducted by an interdisciplinary team, with each discipline contributing collectively to the identification of problems, and identifying and evaluating potential solutions, taking into account factors influencing both the natural and human environment within which farmers operate.

(e). Informal surveys don't permit statistical analysis because they are undertaken without a formal sampling procedure, do not involve obtaining responses to a standard set of questions, etc.

7.2.2 USES OF INFORMAL SURVEYS

In FSR, informal surveys are developed in response to felt needs [CIMMYT, 1985], such as:

(a). The need to help scientists to become acquainted with, and learn from, farmers.
(b). The need to find a method for rapidly obtaining technical and socio-economic information to help researchers in developing relevant improved technologies.
(c). The need to identify a cost effective survey procedure.

Over the years informal surveys have proved to be, when properly executed, a low cost way of obtaining information and opinions from the farmers, of tapping the indigenous knowledge and wisdom that exists on agricultural matters, and of developing a rapid understanding of farmers' circumstances, practices and problems.

Consequently, informal surveys often fulfill four main uses in FSR-type work [Rhoades, 1982; Khon Kaen University, 1987]. These are as follows:

(a). ***The Feasibility Survey.*** Informal surveys can be useful in planning a project in a

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[1]. Two particularly comprehensive books on techniques used in rapid rural appraisal are Khon Kaen University [1987], and Chambers, Pacey and Thrupp [1989]. Also useful is a regularly published series called **RRA Notes**, which is produced by International Institute for Environment and Development, 3 Endsleigh Street, London, WC1H ODD, UK.

region, particularly in cases where relatively little is known. At the beginning of ATIP there was concern about the potentially high logistical costs of interviewing farmers spread over large areas. Therefore, informal surveys were undertaken in the Francistown and Mahalapye areas to ascertain whether the needs of different types of farmers in each region could be captured by confining the bulk of ATIP activities to working with a cross-section of farmers in three villages in each region. We concluded that the variation in the farming systems within the selected villages -- which had different characteristics, such as size, settlement patterns, accessibility to the urban area, etc. -- was as great as the variation throughout the region as a whole.

(b). ***Reconnaissance Surveys To Prepare Formal Surveys.*** The objective of these surveys is to quickly obtain basic information for designing and executing formal surveys or more in-depth investigations which may lead to on-farm experimentation. Such informal surveys help in developing an understanding of the area, and can help ensure that the formal questionnaire is designed in a manner understandable (e.g., in terms, standards of measurement used, etc.) and relevant to farmers' circumstances, and sensitive to local issues, etc. The initial informal surveys undertaken by ATIP, which unfortunately were never well documented, did provide a useful input into the design of the formal village census surveys and detailed formal multiple visit sample surveys undertaken in the early years of the ATIP work[2]. An example of an informal survey from ATIP work, designed to provide some understanding, but which was not intended to provide an input into a formal survey, was undertaken on the interaction between lands areas and cattle posts [Gray, 1986].

(c). ***Informal Surveys For The Direct Planning Of On-Farm Agronomic Trials.*** The formal survey stage is skipped and on-farm experiments are undertaken on the basis of an informal survey which identifies problems that need to be addressed. In fact, much of the ATIP work in the plowing/planting area evolved initially out of the informal surveys supplemented later with data derived from studies and formal surveys.

(d). ***Informal Group Interviews On Selecting, Monitoring And Evaluating On-Farm Trials.*** The literature usually emphasizes the use of informal surveys in the planning stages of FSR work. However, in ATIP work, we also use informal survey techniques in the monitoring and evaluation of on-farm trials, particularly those at the FMFI level. The researcher-oriented farmer groups, provide a particularly good forum for such interaction.

7.2.3 PRECONDITIONS FOR INFORMAL SURVEYS

Although we are convinced of the value of informal surveys, we have not documented its use to the extent that perhaps would be desirable. Overtime we would like to see progressively greater use and acceptance of this approach in Botswana. There are perhaps three critical factors that will be important in determining whether this approach can be used successfully [Khon Kaen University, 1987]:

(a). ***Human Resources.*** Rural rapid appraisal techniques will only give reliable findings if the multi-disciplinary team of researchers are familiar with the techniques, possess interviewing, observational and analytical skills, and can work well together in the field.

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[2]. See ATIP [1986A and 1986B] for some of the results from these.

(b). ***Flexibility In Decision Making.*** Rapid rural appraisal techniques can provide timely information for improved understanding throughout the research process. However, benefits from these inputs will only be achieved if the research program can be structured in a flexible enough manner to permit, and react to, the input of new information as specific research activities proceed. FSR certainly should be able to respond in this manner, but on-station research is likely to be less flexible.

(c). ***Intended Use Of Information.*** Rapid rural appraisal techniques are particularly appropriate whenever open-ended learning is needed or desired, but will not be appropriate when data are required over a long period of time, or when data are needed from a large number of units which are more precise and statistically reliable. However, as implied earlier, rapid rural appraisal techniques can be used to better design and complement/supplement other research methods.

7.2.4 IMPLEMENTING INFORMAL SURVEYS

There are a number of decisions and actions that have to be undertaken in implementing informal surveys. Important points to consider are [Caldwell, Frankenberger, Taylor and Walecka, 1987: pp. 169-174]:

(a). Determine what the major objectives of the survey are to be. These should be finalized after taking into account the needs and inputs of the relevant authorities and interested parties, e.g., FSR, experiment-station based, and extension personnel.

(b). It is necessary to decide on the size and composition of the survey team. Usually the size of the team should be determined by the objectives or focus of the survey, i.e., the more complex the objectives and the more complex the natural and human environment is, the more likely a larger team would be desirable. In general, both technical and social scientists should be included in teams. It is also desirable to have women included on the teams to ensure gender issues are taken into account. Inclusion of extension and experiment station-based personnel can sometimes be useful both in terms of the potential contribution they can make and the professional benefits they can receive as a result of interaction between disciplines and with farmers.

(c). Background information relating to the objectives and area to be surveyed, need to be assembled and digested. Such information can be obtained from: reviewing secondary data -- both published and unpublished -- acquiring maps, and interviewing key informants. These are knowledgeable personnel such as local government officials, leaders, extension and development staff who have good background information relating to the objectives and the area to be studied. Obviously the amount of time required for obtaining and digesting background information will be minimal if the FSR team is already working in the area.

(d). If it is the first time the team is to be working in the area then approval to undertake the survey must be obtained from the appropriate authorities. For FSR work, in Botswana, this usually means obtaining the support of regional and district agricultural officials, and leaders in the villages.

(e). It is desirable to produce interviewing guidelines. These can be divided into two groups: content and process.

i. ***Content.*** These are topical lists to help researchers address topics and aspects of a topic which they might otherwise omit[3]. The list should arise out of a consensus among team members, and consideration of the objectives, background information and prior knowledge of the area. This provides an ideal opportunity for promoting team building as it allows each team member to contribute to the list, emphasizing topics relevant to his/her own interests/discipline. As a result, survey priorities are established before going to the field, and the team begins to operate as a single unit. If possible the topical outline should be tested prior to going to the field. This list should, however, not be considered binding. Sometimes team members may not want to pursue all the topics on the list in order to obtain more detailed information on a particular aspect.

ii. ***Process.*** In addition to deciding on the topics to be addressed in the survey, it is also important to agree on the appropriate interviewing procedures before starting the survey. Topics which might be useful to agree on before going to the field include how to approach the farmer in terms of introduction, interaction, encouraging single or group interviews, length of interview, etc., how to handle translation and sensitive topics, and how to avoid asking biased questions.

(f). Interviewing procedures will, of course, to some extent, be location-specific. Some points that are important to take into account include [Rhoades, 1982: pp. 15-20]:

i. When working in the village for the first time, the objectives of the survey and the proposed approach should be explained to, and approval for undertaking the survey should be obtained from, the village leadership, and if so desired by the leadership, at a village **kgotla** meeting. Such meetings provide an opportunity to obtain general information about the village, institutions, etc.

ii. If the team is large, it is a good idea to break it up into groups of two -- consisting ideally of a technical and social scientist -- to conduct interviews with a range of farmers. These farmers are usually selected in an informal manner; for example, every fifth farmer who is met, a certain number of farmers who have particular characteristics such as being female and head of a household, or who hire draft animals, etc.

iii. There are a number of tips on executing interviews in a way that will maximize the interaction between the farmers and team members and the value of information that is obtained. Rhoades [1982] has identified four stages in the interviewing process[4]:

-- Approach: keep a low profile; interview when it is convenient for the

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[3]. Some researchers feel that such lists tend to be used like questionnaires and may restrict the interview to subjects selected by the researchers themselves. However, we believe that, in the Botswana situation, such lists are justified because many informal surveys are likely to be undertaken by teams that are relatively inexperienced in the implementation of informal surveys.

[4]. Many of the points listed in the following paragraphs have been mentioned in Sections 3.1.2 and 6.3.1.

farming family; whenever possible conduct the interview at the farm.

-- Warm-Up: respect local customs; use a polite form of address; establish collegiate relationships; if necessary make appointments to discuss the survey; take time to approach the survey topics; if desirable indicate you are there to learn and he/she is the expert.

-- Dialogue: be natural and relaxed; let the discussion flow and be flexible with the ordering of the questions; use plain understandable language and terms they can relate to; make sure the questions are culturally sensitive, avoid sensitive questions at first, and if possible obtain such information through indirect questioning; if the farmer can't answer a question, try rephrasing it; don't ask questions that are too abstract; observe the farmer's reactions to questions as these may reveal a great deal about his/her concerns or reservations; remember that what people say and do may be two different things; record the information in writing during the interview only if the farmer does not appear to be inhibited or suspicious; don't let the interview last more than 30-45 minutes unless the farmer is talkative, etc.

-- Departure: bring the conversation to an end when the topics have been discussed or the farmer can spare no more time, thank the farmer for his/her time and depart respectfully.

iv. Rotating team members on a daily basis gives each person a chance to work with and learn from other team members, thereby facilitating the exchange of ideas and helping to establish better communication among team members. It is also a good idea for the team to get together as a whole, on a frequent basis, e.g., daily, to review tentative hypotheses and compare and discuss observations and conclusions that have arisen. Also, at this point, some notes should be made, if not done earlier, to avoid points being forgotten at a later date. Such discussions can help stimulate team members' thinking and result in a modification of the topical outline for further interviews.

v. At the end of the survey, which usually will not last more than a week, a written report should be prepared by team members reflecting a consensus on the hypotheses, findings -- which will usually include information on farmers' attitudes, constraints and indigenous knowledge -- and recommendations for future action.

A good example of where this approach has been used in ATIP work, is the cattle post-lands interaction study referred to earlier [Gray, 1986].

7.2.5 USE OF INFORMAL SURVEY TECHNIQUES IN ON-GOING ATIP WORK

A great deal of ATIP's day-to-day work involves using informal survey methods which include one or more of the elements discussed above. Obviously once familiarity with the area and individual farmers has been established, many short cuts can be made in the implementation procedure, although it is always important to bear in mind some basic principles, e.g., use terms farmers can relate to, develop a collegiate or partnership type relationship, etc. We use informal survey techniques in many situations, for example:

(a). Consultations with individual farmers on their farms concerning the practices they are

using, the trials they are participating in, etc.

(b). Farmer field days in which farmers play prominent roles.

(c). Farmer groups (i.e., both researcher and extension-oriented) where farmers out number the outsiders (i.e., researchers and extension staff), and as a result farmers often express their views quite vigorously.

These forums provide important opportunities for learning from the farmer in order to help in planning, implementing, monitoring and evaluating formal surveys, studies and trials. Because a good deal of this information is not formally documented, we tend to forget the significance of this informal interaction in shaping our thoughts and actions. Indeed, it is probably true to say that several of the strategies that have been developed in the trials over the years were stimulated in such discussions. Two examples are:

(a). In the Mahalapye program, it was observed that many farmers recognized high potential sites on their fields where soils were deeper, had a relatively high clay fraction, and tended to be at the bottom of slopes. These characteristics create conditions conducive to high water retention, important in the drought prone environment of Botswana. Consequently, some farmers use strategies to take advantage of these high potential sites. As a result, ATIP researchers have also accepted the potential payoff from targeting strategies towards these high potential sites by implementing trials on manure and phosphate application.

(b). ATIP has done a lot of trial work on double plowing. Since, at times, the traditional plowing/planting system can be effective if soil moisture conditions are satisfactory, farmers in Matobo village indicated that they could reduce the cost of the first plowing in a double plowing system by doing it when the soil moisture conditions were not suitable for planting, therefore not sacrificing potential production. This observation encouraged us to rethink our position on double plowing strategy as a substitute for the traditional system. Instead it should be viewed as an option for the farmers to pursue for increasing the potential number of days planting can be done on subsequent rains.

Before finishing this section the idea of group interviews or interaction is briefly discussed. This strategy is an important part of ATIP's program because of the emphasis on researcher and extension-oriented groups. Discussion on the organization and operation of these groups is presented elsewhere in this handbook (see Section 13.1). We have found that these groups are an effective forum for obtaining general information on the relevance and value of technologies being offered to farmers, on producer prices for products in an environment where there are no physical markets or market days, on aspects that affect all farmers (e.g., comments on ARAP, ALDEP, etc.), on controversial issues (e.g., availability of inputs), on trends (e.g., fertility, draft type, etc.), general opinions on issues, information on variability (e.g., types of farms, farming systems, planting patterns), etc. In Botswana, obtaining information from farmer groups has been particularly useful because:

(a). The members of the group have been together for sometime, therefore interaction between the farmers themselves, and between the farmers and the "outsiders", is more relaxed, creating the potential for more productive discussions.

(b). The cultural setting is such that discussion is not inhibited between farmers in different recommendation domains, thus creating potential for greater variability in the views expressed. Also the majority of the individuals attending the meetings are women, some of whom come from male-headed households.

The one concern that has been raised about the group interaction that ATIP is involved with is that there is a danger of some of the groups becoming too big for productive interaction [Ntseane, 1988]. We are not yet sure at what size of group a breakdown in communication is likely to occur, but once this is known the solution is easy -- break the group into two.

7.3 FORMAL SURVEYS

7.3.1 INTRODUCTION

In the introduction to this chapter (Section 7.1) we noted some of the characteristics of formal and informal surveys. It is obvious that both types of surveys have important roles to play in FSR. Informal surveys can, amongst other roles, make an important contribution to the design of the more expensive, time consuming formal surveys. However, these formal surveys are still cheaper and less time consuming than direct measurement. Formal surveys involving the use of questionnaires provide a systematic, ordered way of obtaining information from respondents, and enable precise and statistically analyzable data to be obtained.

Some of the strengths and weaknesses of formal surveys are presented in a table in Frankenberger and Walecka [1987: pp. 190-191]. Earlier in the handbook, we indicated formal surveys can be divided into single (one-shot) and multiple (frequent) visit surveys (Section 2.5.1).

Two major concerns have preoccupied us in the use of formal surveys in ATIP work. These are to ensure that:

(a). The benefits from such surveys justify the costs involved.
(b). That there is a reasonably quick turnaround in terms of incurring the costs and reaping the benefits.

At the beginning of ATIP, Multiple Visit Resource Unit (MVRU) Surveys were undertaken to obtain information on the inputs and returns from the farming systems practiced by a small sample of representative farmers (i.e., see Form A2.2 in the Annex Volume [Worman, Norman and Ware-Snyder, 1990]). These surveys did yield useful information, but the research resources required -- in terms of level and time -- and the slow turnaround time in terms of the results not being available until much later, convinced us of the limited relevance of multi-purpose surveys feeding, in a timely manner, into new research initiatives.

Consequently in most of ATIP's existence we have tried to address the concerns mentioned above in the following ways:

(a). Emphasizing special subject surveys with limited objectives rather than more general multi-purpose surveys.

(b). Implementing single visit rather than multiple visit surveys.

(c). Carefully considering how accurately individual variables need to be estimated in order to answer the objectives of the survey (see Section 2.5.1). Relative rankings may be sufficient, or if accurate measurements are required, a direct measurement rather than using a survey format may be more appropriate. Yet another alternative may be to use "standard coefficients" obtained from other work for variables that are not critically important or are fairly predictable. See Section 8.4.3.4(b) for further

discussion on this[5].

(d). Making sure the links between data collection and checking, followed by microcomputer data entry, processing, analysis and writing up are made as efficient as possible.

If the need arises, it should now be possible, with the system we have developed over the years, to design, implement, process, analyze and write up the results of a reasonably long, single visit, special subject survey of 100 households in a period of three months, half of which could be devoted to the design and implementation stages.

However, a key pre-condition to make this possible will be the ease of selecting samples. Generating the sample frames, selecting samples, determining the required sample sizes and designing questionnaires are all important ingredients in determining the value of formal surveys. These are discussed in the following sections.

7.3.2 SAMPLING[6]

7.3.2.1 Why Is Sampling Necessary?

There would be no need to worry about a sampling procedure if the characteristics of all members of a population were exactly the same. It would only be necessary to select one individual to identify the population characteristics. However, because of diversity in the technical and human environment it is necessary to sample several members of the population before any conclusions can be drawn.

Therefore the purpose of sampling is to select a subset of the population which has the same characteristics as the whole group or is representative of the population. The term population refers to all of the elements -- such as farms, households, etc. -- from which the sample is actually selected, while a sample is a representative portion of the population under study.

7.3.2.2 Activities Required In The Sampling Process

The sampling process requires six activities:

(a). Specification of the sampling unit.
(b). Preparation of an adequate sample frame (list) of these units.
(c). Selection of the sampling method.
(d). Determination of the sample size.

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[5]. In certain situations, an alternative, which we have not used to date, would be to have two levels of a sample. For example, a single-visit survey would be administered to a large sample, would concentrate on single point registered data, and would -- because of its size -- result in relatively low sampling errors. The other sample, being much smaller, would be a subset of the larger, would involve more than one visit to collect the data, and would concentrate on minimizing measurement errors of continuous, non-registered types of data (see Section 2.5.1).

[6]. Notes for this section draw heavily on material in CIMMYT [1985: pp. 70-78] and Shaner et al., [1982: pp. 303-306].

(e). Selection of the sample.

These activities are briefly discussed in the following sections. However, before doing so, the issue of stratification which underlies many of the sampling techniques, is briefly examined.

7.3.2.3 Stratification And Recommendation Domains

Stratification of the population is the process of dividing the population into subgroups called strata, and then taking separate samples for each group or stratum. The sample within each stratum should have the same characteristics (i.e., be homogeneous), while differences between samples in different strata will be maximized and therefore reflect the heterogeneity in the population. Whenever possible, it is good to choose strata that correspond to the different types of farmers that are to be helped. CIMMYT calls these different types, recommendation domains [Byerlee et al., 1980: p. 71]. A recommendation domain is thus a group of roughly homogeneous farmers with similar circumstances for whom we can make more or less the same recommendation. Recommendation domains may be defined in terms of natural factors (e.g., rainfall) and/or human factors (e.g., area cultivated, traction type, etc.).[7] For example, in early ATIP work, we recognized that all farmers had one major constraint in growing crops (i.e., limited water). Therefore, recommendation domains or strata have been based on the notion that the degree to which limited water can be used in encouraging crop growth will depend on the resources farmers have at their disposal (e.g., wealth, traction type, etc). Thus, there are different types of solutions for different types of farmers, classified according to an economic criterion. This resulted in the definition of different recommendation domains based on type of, and accessibility to, draft. Thus in some of our work we have used as many as six strata. For example, those who use their own donkeys, oxen or tractors, and those who hire/borrow donkeys, oxen or tractors.

7.3.2.4 Sampling Unit

As we indicated above, whenever we want to know more about the population, we have to focus on units such as villages, farming families, fields, etc. These are called the sampling units or sometimes the unit of direct data collection. We have to say what type of sampling unit we want to study. The choice of the sampling unit depends on the purpose of the study or survey. This choice is an important step because it determines what sampling methods a researcher uses, and helps identify lists from which researchers sample. In most ATIP work, and in fact in most FSR work, sampling units have usually been household/farming families. However, for certain types of surveys or trials, the sampling unit may be a field of a particular soil type, a field located in a certain position in a topo-sequence, a family owning a Sebele row planter, etc.

7.3.2.5 Preparing A Sample Frame

A sample frame is a complete list of all the population which is to be sampled. The sampling unit determines what sample frame is required. As has just been indicated, in farming systems work, the most commonly used sampling frame is a list of all the farming families. It could, however, depending on the objective of the research, be a list of all fields, a list of farming families who own Sebele row planters, etc. A sampling frame is

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[7]. A more detailed discussion on recommendation domains is given in Section 2.3.

needed in order to select a sample from which data are collected. Data could be collected from the population as a whole, but the reason why a sample is usually selected is to reduce costs (time, money and personnel) of the research. If the sample is selected correctly then valid generalizations can be made about the population as a whole.

Developing a proper sampling frame and drawing a reliable sample are probably two of the most difficult parts of data collection in FSR work. In Botswana we have never found a ready made, perfectly complete sampling frame to use in our work.

Some examples of possible sample frames that could be used in Botswana are as follows:

(a). Lists of farmers kept by ADs.
(b). A list of people receiving food at schools/clinics during a Drought Relief Programme.
(c). Lists of farmers participating in government production campaigns such as ALDEP, ARAP, etc.
(d). A list of households associated with a community development project.
(e). A list derived from sources outside the village, for example, a census listing.

The problem with these types of lists or proposed sampling frames is that they are drawn up for particular purposes and may not be a complete list of the population as a whole, and thus may be biased. Not all biases need to be avoided, but it is important to be aware of the ones which do, or may, exist. Some of the more common biases identified by Sutherland [1988: pp. 2-3] are:

(a). ***Middlemen Bias.*** When a middleman, such as the extension agent or a local leader, provides a list or recommends a group of farmers there is often a bias in favor of more progressive farmers, male-headed households, and friends or family of the middleman.

(b). ***FSR Team Characteristics.*** Farming systems teams may have internal biases resulting in a gender bias (favoring either male or female participants), a language bias, or an innovator bias. Also, there may be a bias because teams have a preconception, inappropriate definition or a lack of understanding about what constitutes a farmer and/or a household.

(c). ***Logistic Factors.*** These may be some of the most difficult biases to avoid, and involve a bias towards farms with lands areas near roads, and a bias towards working with progressive farmers in order to show results.

(d). ***Local Circumstances.*** Other biases can arise from local circumstances depending on the ecology, geography and social structure of the village. There may be a bias to "home centered farmers" when farming is a seasonal activity, and away from farmers who leave the area for certain periods of the year in order to find wage employment.

When selecting samples from lists, these possible problems should be remembered and, if necessary, adjustments should be made to the list. This has been possible in some of the more recent surveys, as our in-depth knowledge of the ATIP villages has grown over the years.

If drawn up carefully, the most comprehensive sampling frame is to do a complete census of the population (e.g., farming families). However, doing this can be very time consuming and expensive and, if not done carefully, can miss some of the population. Also, if not done carefully, it can still contain biases -- for example, see point (b) above. At the beginning of the ATIP project, we did in fact do a complete census in five of the six

villages where we have concentrated our work[8]. In some of the villages, the census was done with the help of enumerators employed in the Agricultural Statistics Surveys implemented by the Division of Planning and Statistics in MOA. Physical residences were identified with the help of maps drawn up for the nationwide census that had just been carried out[9]. Demographic and a small amount of agricultural information, to help in stratification exercises (e.g., type and degree of control of draft), were collected in our census of each household. We have continued using this sampling frame over the years, although obviously it has become somewhat dated, and on occasion has been supplemented by lists of households derived from other sources. Perhaps, ideally, such a census should be carried out once every five years, but preoccupation with other tasks, and the time and research resources required for doing it, have precluded us from repeating the exercise.

An approach, that to date has not been used in Botswana, but has proved to have considerable potential in other countries, is the use of mapping techniques. A group of knowledgeable villagers are brought together and are asked to construct on paper, or in model form on the ground, a map of the main features in the village, including compounds. It is quite possible that, between them, they are able to attach names of the household heads in each compound and also provide some information on critical characteristics, e.g., what type of draft does the household use, do they own or hire the draft, do they own row planters, etc. Therefore, there appears to be considerable unexplored potential for drawing up sample frames using this approach[10].

With the possible exception of mapping techniques, there appears to be no easy solution to coming up with a complete sample frame. Unfortunately, if the sampling frame that is used is incomplete, then the purpose of sampling is defeated. The reason is that the researcher cannot then make accurate generalizations about the population as a whole -- for example, for farming families that are not present in the sampling frame. The important thing to remember is that the sampling list should therefore be as complete as possible.

7.3.2.6 Selecting The Sampling Method

There are two types of samples:

(a). ***Probability (Random) Samples.*** This is the term used to describe the various ways of drawing a sample such that the probability of, for example, a particular family being included in the survey, is known or can be established with reasonable precision. For this type of sampling, an appropriate sampling frame must be available. The advantages of probability sampling are:

i. The risk of bias in selecting the sample is minimized.
ii. It is possible to draw inferences for the population (e.g., of families) with levels of confidence that can be estimated statistically.

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[8]. It was never done in Makoro where we started work later.

[9]. Ideally, it would have been good to have used the list of households drawn up in the national survey. Unfortunately, because of reasons of confidentiality, it was not possible for us to obtain any disaggregated information on the villages, apart from the maps.

[10]. Further information on these techniques can be found in Chambers, Pacey and Thrupp [1989]. Also useful is a regularly published series called **RRA Notes**, referred to earlier in this chapter -- see Section 7.2.1.

Sampling error can thus be estimated. The sampling error is a measure of how close the sample represents the larger population. It consists of two elements: the confidence interval and the confidence level. For example, researchers might report that they are 95% confident that between 40 and 50% of the farmers in the area use fertilizer. This means that 95% of the time the interval, so calculated, will actually contain the true value for the whole population. In this example 95 percent is the confidence level and 40% to 50% of the farmers using fertilizer is the confidence interval, i.e., 45% plus or minus 5%.

(b). ***Non-Probability (Nonrandom) Samples.*** This type of sampling is used when probability sampling is not possible (practical). This is because no sample frame is available or if it is, it does not contain the information necessary for stratification. Nonrandom sampling cannot produce data from which researchers can generalize to larger populations. The reason is that the researchers have no way of knowing whether the individuals interviewed represent the population being studied. However, such interviewing does provide researchers with a feeling about a population which sometimes justifies the use of the method.

Four major methods of probabilistic (random) sampling used in farming systems work, are as follows:

(a). ***Simple Random Sampling.*** In this case, each unit in the population has the same chance of being selected. A predetermined number of units are selected at random from the population list or sampling frame. Advantages of this method are that it is easy to implement, and it is appropriate if the population is concentrated in a single area. However, it is not appropriate if:

i. The selected units are geographically dispersed and therefore will be expensive to reach.
ii. When the population characteristics are variable, it will provide imprecise estimates.
iii. If the population is not truly homogeneous, it will affect representativeness.

(b). ***Systematic Sampling.*** In this case, the researcher starts with a random number on the list and takes every k^{th} unit on the list, for example, every fifth on the list after starting at 18[11]. Usually this method is preferred over simple random sampling because it is quicker and easier to use. However, one must be sure that the units are listed randomly on the sampling frame list, otherwise it can lead to biases.

(c). ***Stratified Random Sampling.*** Here researchers separate the units into strata with the desired characteristics, and then randomly select samples of units from each stratum. For example, we may have different strata defined according to type of traction used and ownership of traction used. The strata chosen should be relevant for the research objectives and population, be easy to use, and contain enough units so that statistically reliable comparisons can be made. The main disadvantage of stratified random sampling is that the researcher must know about the population being studied so as to place the units into the proper strata. In farming systems work this stratified random sampling system is used whenever possible. This is because:

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[11]. The sampling interval 'k' is determined as follows: $k = N/n$ where N is the total number in the population being sampled and n is the required sample size.

i. It is easy to carry out.

ii. It is more efficient than simple random or systematic sampling because the selected sample is more likely to be representative of the population from which it is drawn. It therefore increases the precision of statistical estimates by minimizing the variability within strata, and maximizing the differences or variability between strata.

iii. It is useful in getting more information from the entire population.

(d). ***Cluster Sampling.*** Cluster sampling, which is sometimes called ***Two-Stage Sampling,*** involves obtaining a list of geographically grouped units and then selecting units from the sub-lists. Such an approach reduces the cost of interviewing farmers because they tend to be close together. It also does not require a full sampling frame. However, sampling biases may be introduced because geographically close units may be more similar to each other than are dispersed units. For example, in farming systems research we often select a few villages to work in, and then select farmers from within each village. Over the years we have decided that, in fact, there is a great deal of variation within villages, and selecting villages that have different characteristics does provide a reasonable representation of the population as a whole. A more complicated type of cluster sampling is ***Multi-Stage Sampling,*** while another variation is called ***Section Sampling.***

Unfortunately practical problems, such as lack of a sampling frame, lack of funds, problems of substituting farms due to non-response, and problems of accessibility, often means using nonrandom sampling more often than would be desirable. There are two major types of nonrandom sampling used in farming systems work. These are as follows:

(a). ***Purposive Sampling.*** In this case a decision is made about a series of characteristics that are wanted in the sampling units. Then, without using a population list or indicating selection procedures, sampling units are selected and interviewed that meet the desired characteristics of the population. For example, we may wish to interview farmers who have to hire donkeys. In such a case we would then try and find farmers who fall into this class, and interview them until the number that we want have been interviewed. Another example, we have used recently, is in a survey designed to assess the condition of row planters. In this case we identified and interviewed farmers who owned row planters.

(b). ***Quota Sampling.*** This can be used where we want to stratify samples and we have a sampling frame (list) for the whole population, but it is not broken down into strata. In this type of sampling we select at random from the overall population list (sampling frame) and then start the interviews with the farmers by asking a number of questions that indicate which stratum they fall into (e.g., hire donkey traction, use own oxen, etc.). If these questions place the farmer into a particular stratum and the quota has not been filled, the enumerator completes the interview. The process is continued until the quota for this stratum is filled. Quota sampling cannot be used to generalize about the stratum characteristics because the number of persons to be interviewed, in each stratum, was specified by the research design, and is not necessarily representative of the whole population.

Obviously there are a number of sampling methods that can be used in selecting samples. Which should be used? Ideally, stratified random sampling probably would be best. However, of course, FSR work is not undertaken in an ideal setting. Practical realities make compromises necessary. Thus, a number of factors have to be considered before selecting

the sampling method for a particular survey/study. These need to be considered in the following order:

(a). At the start, it is necessary to consider what data are needed, and the generalizations that the FSR team wants to make about the target population.

(b). This in turn will influence the research design for the study.

(c). With the desired research design in mind, the availability of sample lists (sample frames) must be considered. Factors in deciding the amount of effort to be devoted to drawing up a sample frame are available funding, the time required and needed for the research design, and the expertise or the experience of the key research staff.

(d). After weighing up these factors, it will be necessary to select the sampling method that best fits the needs. Usually in farming systems research random sampling techniques are used as much as possible, and, if feasible, stratified random, cluster or systematic sampling techniques -- since these can reduce the cost and/or sample size required. For initial information about the population, or if the relevant sampling frame is too expensive or impossible to obtain, then it is often necessary to use nonrandom techniques such as quota and, as a last resort, purposive sampling.

In actual fact, in a good deal of our current work, no formal sampling procedure is used. This is true with respect to the farmer groups operating in the ATIP villages which anyone can join. The members select the technologies they wish to test, and as members of the groups are automatically selected for certain surveys (e.g., End-Of-Season Survey).

At times an entire population may be surveyed and not just a sample of the population. For example, in the case of End-of-Season Surveys of farmer group members we usually try to sample all of the members who participated during the current year. Also in a study such as the Adoption Study we try to interview all members of the farmer groups. In this case we are interviewing all members of a given population rather than taking a sample of the population. If we are interviewing all members of the population we can describe our results in terms of the population since we are not estimating population parameters (means, standard deviations, etc.) based on a sample, but are in fact able to give the actual population means etc. This has certain consequences for the statistical analysis of this data because it is not appropriate to talk about sample characteristics such as confidence intervals for the means, etc. There are cases where the study populations may be a sub-population of a larger population, such as all of the farmers in a village, but whether the sub-population is a valid sample of the larger population must be determined on a case-by-case basis as the sub-population may not be a statistically valid sample of the larger population[12].

7.3.2.7 Determining Sample Size

There are a number of factors that influence the sample sizes used in farming systems work. These include:

(a). Variability of local farm conditions.

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[12]. This is particularly a problem with a self-selected group, such as the farmer groups, as there is no sampling procedure involved and it is only possible to compare population characteristics of the sub-population and the larger population to see if the sub-population appears to be reasonably representative of the larger population.

(b). Degree of precision required.
(c). Available time and research resources.
(d). Type of data handling facility.
(e). Details and complexity of the questionnaire.

There are many formulae in statistical text books for determining the optimum sample size, based on the degree of accuracy with which the researcher wants to measure a particular parameter. It is important to understand that the appropriate sample size depends on the variability in the population and not on the size of the population. Therefore, the percentage of farming families which must be included may vary substantially between recommendation domains.

Unfortunately, in farming systems research many different parameters are often estimated and thus each would require a different sample size to obtain a particular level of accuracy. Also as indicated above, there are practical considerations that influence what sample size is feasible.

Researchers generally increase the sample size to reduce the standard error -- a measure of sampling error. But as the sample size increases so do sampling costs and often a high level of precision is not worth the additional cost. For many types of farming systems work, budget restrictions have more of an influence on sample sizes than do researchers' desire for precision.

As a result, a number of people have recommended that researchers sample enough units from the population to have a minimum of 20 cases for each sampling category [Yang, 1965, p. 9; Shaner et al., 1982, p. 306]. CIMMYT [Byerlee et al., 1980: p. 47] has found that 30 to 50 farmers for each recommendation domain will usually reflect reasonably well the circumstances of farmers in that recommendation domain. One point to bear in mind when selecting the sample at the beginning, is that it is a good idea to select more units than will be needed in case some of the sampling units are later found to be unavailable or unsuitable.

7.3.2.8 Concluding Remarks On Sampling

Hopefully, once you have gone through the above steps, you are now ready to select the sample! However, making decisions about the sampling procedure and sample size can be quite complex. If you have doubts about the best way to select a sample and/or the size of sample that is necessary, then either look at some of the voluminous literature which is available, or obtain the help of the biometric staff in DAR.

In conclusion, bear the following points in mind when making decisions about sampling:

(a). Be pragmatic.
(b). Sample design and logistics of field work are often complementary.
(c). Statistical desirability and practical feasibility often conflict.
(d). Knowledge of the area and the subjective judgement of researchers are crucial in selecting villages and samples.
(e). Use the simplest procedure -- that is, in terms of costs and resources -- that will permit the achievement of the research goal.
(f). Remember biased selection of farmers will give rise to biased answers and conclusions. Both researchers and extension staff can be guilty of selection biases.
(g). Use probability sampling whenever possible, but in any case, always be aware of the limitations of the method that is used.

7.3.3 DESIGNING QUESTIONNAIRES

There is a logical sequence to producing a good questionnaire. Shaner et al., [1982] divide this process into six steps: determining data needs, determining question content, determining question format, determining the question wording, deciding on question sequence, deciding on physical length and layout, and undertaking pretesting and revision. Each of these steps are now looked at in a little more detail.[13]

7.3.3.1 Determining Data Needs

A good approach to ascertaining the specific information needs is first to determine why the survey is required (i.e., justification) and therefore the objectives of the survey. The need for the survey and the objectives that are developed, initially come from a review of secondary data, results from informal surveys, and expressed needs of interested parties (e.g., FSR researchers, station-based researchers, extension/development staff, planners, etc.). These sources can help in formulating tentative hypotheses which help to focus the survey designers' attention on specific topics, and on what additional data are required. Where information on both the natural and human environment are to be collected, determination of the data required and the design of the questionnaire itself should be a collaborative effort of technical and social scientists.

There is more than one dimension to determining data needs. Such needs should not only be viewed in terms of variables on which information is required, but also in terms of the degree of precision with which they need to be measured. Making a decision at this planning stage on the type of analysis proposed can help in determining the answer to this and the cost of collecting the data (see Section 2.5).

7.3.3.2 Determining Question Content

There are three important issues to address with respect to question content:

(a). Appropriate identification information and variables should be placed at the beginning of the questionnaire, such as the title of the survey, the name of the organization undertaking the survey, identification of the interviewer and the person being interviewed, the date and place of the interview, etc. A unique identification number of some type provides a sense of order to the data. This number facilitates data entry, checking and analysis of the data on the microcomputer.

(b). Variables need to be included that enable the sample to be appropriately classified or stratified. In FSR work, as has been discussed elsewhere in the handbook (see Section 2.3), households are usually stratified in some way into recommendation domains. In ATIP's work, important classification variables that have been used include draft type and degree of control, wealth of household as indicated by the number of cattle owned, gender and age of household head, size of household, etc. Even if a sample selected were stratified according to one of these variables, it is still important to collect the information on the stratification variable to make sure

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[13]. Most of the material for the following discussion came from Shaner et al., [1982: pp. 299-302], Frankenberger and Walecka [1987: pp. 194-196], and Yang [1965: pp. 11-14].

that the household is in the correct stratum. Inclusion of possible classification variables in the questionnaire is important to enable meaningful comparative analysis to be carried out later.

(c). Obviously questions must be developed for each of the variables in the hypotheses and a determination must be made of the farmers' ability and likelihood of answering the questions. Three points that are particularly relevant with respect to farmers answering questions are as follows:

i. Questions must use terms and units of measure (e.g., for weight, area, distance, etc.) that the farmers in the area are familiar with. Conversion to more generally used units and measures (e.g., kgs, hectares, etc.), should be done later by the researcher using conversion ratios that have first been established (see Section 8.4.3.5).

ii. Questions should not be used that require calculations (e.g., average bags of sorghum per hectare) by the farmers. Any calculations required should be done during the analysis stage. The information needed for the calculation can be collected during the interview (e.g., number of bags of sorghum harvested, and the number of hectares on which sorghum was grown).

iii. Special care should be taken over questions that are sensitive. Sometimes sensitivity can be avoided by approaching the issue in a less direct manner. In ATIP's work, we have rarely asked how many cattle households own, but rather, ask if the number of cattle they own fall into particular ranges, e.g., 0, 1-20, 21-40, etc. If a sensitive question cannot easily be avoided, then there is merit in asking the question near the end of the interview so that the interviewer-interviewee (respondent) relationship is not ruined earlier when less sensitive information is being collected.

7.3.3.3 Determining Question Format

There are four categories or classes of questions generally used. These are:

(a). ***Open-ended questions*** -- where the interviewer writes down the response in full.

(b). ***Close-ended (multiple choice) questions*** -- where the enumerator checks the appropriate response category (e.g., marking the Sebele plow-planter box in response to the question "What type of row planter do you own?").

(c). ***Dichotomous questions*** -- where only two responses are allowed (e.g., yes/no, sell/consume, etc.).

(d). ***Tabular questions*** -- where a question is asked after which rows and columns in a table are completed (e.g., information on the type, amount and source of different types of seed that were used, are recorded).

There are advantages and disadvantages attached to using each of these classes of questions. Shaner et al., [1982: p. 301] present a table indicating these. In ATIP's work we have, whenever possible, tried to do the following:

(a). Used dichotomous questions as lead-in questions, to determine whether or not the following questions should be completed. For example:

(5). Do you own a row planter? Yes _____ No _____

If the answer is 'No' go to Question (7).
If the answer is 'Yes' answer Question (6).

(b). Used a small modification of the close-ended questions by giving a choice of responses, but also leaving space for a response that cannot be classified in any of those listed. For example:

(6). What type of row planter do you own?

1. Sebele Row Planter _____
2. Sebele Plow Planter _____
3. Safim _____
4. Other (Specify) _____

On occasion we have also used:

(a). Open-ended questions to obtain opinions (e.g., advantages of row planting) or when we have had difficulty coming up with categories before the survey. Later these responses are post-coded by the researcher, prior to the information being entered on the microcomputer.

(b). Tabular questions when there is a lot of quantitative information to be collected that has a comparable general format (e.g., time spent by male, female and children labor on different field operations). These types of questions were extensively used in the multiple visit (MVRU) surveys, undertaken in the early days of ATIP.

7.3.3.4 Determining The Wording Of Questions

There are a number of guidelines to take into account in the wording of questions. Some of those suggested initially by Bernsten [1979] and discussed with examples in Shaner et al., [1982: p. 301] include:

(a). Every question should focus on one point and have only one answer.

(b). Questions should not contain vague words such as many, often, and frequently. Questions should also be specific. Broader general questions are better asked in informal surveys.

(c). Every question should use terms the farmers commonly use rather than technical terms of the researchers -- see also discussion under Section 7.3.3.2 above.

(d). Every question should be neutrally phrased to avoid biasing the respondent. This includes words or phrases that are emotionally charged or those that suggest approval or disapproval.

(e). Questions should be phrased so that the respondent cannot feel which answer is preferred.

(f). Questions should specify the relevant time period for consideration.

(g). Some questions (e.g., on management practices) can often be clarified by increasing the similarity in the way a number of related questions are asked.

(h). Frequently a pre-qualifying question may be necessary to verify that the question of interest applies to the respondent -- see also discussion under Section 7.3.3.2 above. Such pre-qualifying questions can reduce the chances of collecting misleading, confusing or incorrect information.

(i). Questions on management practices should be asked with respect to individual plots. A tabular question often works well in such cases.

(j). Questions that require accurate answers for aggregate values will be more reliable if the amounts are first collected on an individual basis (e.g., weekly, monthly, or per parcel basis), and then summed by the researchers -- see also discussion under Section 7.3.3.2 above.

(k). Each question should be numbered to aid in the processing of data. With respect to facilitating the collection-entry-analysis linkage, we try and enter the data into the microcomputer straight from the survey form. This cuts down the possibility of errors in the collection-entry stage. To facilitate entry, we record the name of the variable -- as it will appear on the microcomputer -- on the survey form itself during the design stage, and provide a space for entering the figure that will appear in the computer. For example:

(6). What type of row planter do you own?

1. Sebele Row Planter _____
2. Sebele Plow Planter _____ TYRP ____
3. Safim _____
4. Other (Specify) _____

7.3.3.5 Deciding On Question Sequence

Questions should be presented in a way that is logical from the farmer's standpoint, starting with the simple, more general questions and proceeding to the more specific, difficult and sensitive areas. On occasion, it may be desirable to break the logic or sequence of questioning to prevent leading farmers to what they believe are the expected answers. For some data it may be advisable to check the validity of the farmers' responses by asking the question in more than one way.

7.3.3.6 Physical Layout And Length

The beginning of the survey form should, in addition, to including identification and classification type information and data (see discussion under Section 7.3.3.2 above), should also have, where desirable, information that the interviewer can give the farmer on the purpose of the survey, who is being interviewed, etc. Any instructions on completing and coding the form for entry into the microcomputer should also be given at the beginning of the survey form, or at relevant points on later pages. Sufficient space for recording responses and any remarks should be provided on the survey form itself. To easily read the remarks and responses, it is a good idea to provide lines for the interviewer to write on.

In general, the length of interview should not exceed one hour. If it takes longer, the

questionnaire should be divided and administered on separate days.

7.3.3.7 Pretesting And Revision

After the initial design of the survey, it is worthwhile to ask interested and knowledgeable individuals for comments and suggestions for improvements. After making any changes that appear desirable, it is a good idea to pretest it with a limited number of farmers, after which changes can be made prior to its reproduction and implementation. These types of checks can help in:

(a). Determining whether questions are properly worded, understandable, sensitive, irrelevant, etc.
(b). Checking questions for adequacy of format and sequencing, adequacy of categories in close-ended questions, etc.
(c). Identifying missing information, estimating time requirements for the interview, testing the training and understanding of interviewers, etc.

7.3.3.8 Concluding Points

The above discussion on questionnaire design is very brief. Fortunately there are many references available which can provide detailed information on designing surveys. Some of the more useful ones are given in Section 7.5. Also samples of many of the survey forms used in ATIP work are available in the Annex Volume [Worman, Norman and Ware-Snyder, 1990]. It should be noted that many of them do contain flaws -- we have learnt through experience. Remember that a well prepared and laid out survey form can save substantial interviewing time.

In conclusion, although strictly not part of this section, it is important to emphasize that whenever feasible, the survey designers should train the enumerators in completing the forms, should supervise implementation in the field, and should check the forms in the field -- if necessary returning them to the enumerators for correction -- before bringing them back to the office for entering on the microcomputer.

7.4 THE SPECIAL CASE OF SOCIO-ECONOMIC DATA

This chapter discusses surveys. Surveys are most commonly used in FSR to collect social and economic data and farmer evaluations of trials. Because surveys are the primary means of collecting socio-economic data, this section presents some ideas on the use of such data.

7.4.1 WHY COLLECT SOCIO-ECONOMIC DATA?

Socio-economic data are collected for a number of reasons. Some of the most common reasons are:

(a). Problems in an area must be identified.

(b). The FSR team needs to identify villages in which to work.

(c). There is a reason to establish a baseline description of a village or an area that can be used to measure changes at a later date.

(d). The team has specific questions that need answering, for example, how many farmers have adopted a particular practice.

(e). An integrated research approach requires the collection of socio-economic data on agronomic and animal science trials so that economic interpretations of the results can be made.

(f). The team wishes to monitor a set of activities in an area to find out if change is occurring over time.

Basically economic data are collected to answer questions. The questions may be simple or complex. The amount of data needed to answer each question will vary as will the best way to collect such data. Perhaps the most important starting point is to have a good idea of what questions need to be answered, **before** starting to collect the data.

7.4.2 HOW ARE SOCIO-ECONOMIC DATA COLLECTED?

Socio-economic data can be collected in a number of ways. A few of the most common are listed here, and discussed in more detail in other sections of the handbook.

(a). Use of secondary data such as other studies, maps, aerial photographs, etc.

(b). Informal surveys including:
- i. Informal interviews with elected leaders, government officials, and other key members of the community.
- ii. A visit to the area to observe (windscreen survey).
- iii. A Rapid Rural Appraisal or "Sondeo" type of study.

(c). Formal surveys including:
- i. Formal interviews with elected leaders, government officials, and other key members of the community.
- ii. General one time surveys to collect baseline information.
- iii. Multiple visit surveys to collect data over a period of time.
- iv. Special one time surveys to collect data on a single subject.

(d). Data collected (by direct measurement) during an agronomy or animal science trial.

An additional important source of data on an area, trial, survey or study is direct observation by the researchers of what is happening, and discussions researchers have with farmers. These observations and discussions are important in gaining an understanding of why farmers make certain decisions, and for placing the data collected in other ways in context.

7.5 USEFUL REFERENCES

Section 7.2:

Chambers, Pacey and Thrupp, 1989.
Frankenberger and Walecka, 1987: pp. 167-175.
Gray, 1986.
Khon Kaen University, 1987.
Ntseane, 1988.

Shaner, Phillip and Schmehl, 1982: pp. 289-292.

Section 7.3:

Andrew and Hildebrand, 1982: pp. 47-56.
Bernsten, 1979.
Caldwell and Walecka, 1987: pp. 287-292.
CIMMYT, 1985.
Fink and Kosecoff, 1985.
Frankenberger and Walecka, 1987, pp. 187-196.
Shaner, Philipp and Schmehl, 1982: pp. 299-307, 341-350.

Section 7.4:

Caldwell and Walecka, 1987: pp. 271-272, 284-285.

CHAPTER 8: CROP PRODUCTION TRIALS

8.1 PLANNING TRIALS

This section is a brief overview of the general procedures involved in implementing on-farm trials for crops research. Most of the procedures referred to are discussed in detail in other sections of this chapter.

8.1.1 GETTING STARTED

Once research priorities have been identified within the research program, and suitable hypotheses have been developed for testing, the trials work can begin. The first requirement is for researchers (and participating farmers, if appropriate) to define the trial objectives as specifically as possible. This is vital because the trial objectives will determine what trial designs and formats are used, and what types of data need to be collected. For researchers who are not entirely confident of their understanding of statistics, it is always good to involve a biometrician from DAR at this stage to ensure that trials are properly designed, can be properly analyzed, and will answer the pertinent questions. A brief discussion of some of the common trial designs and appropriate formats is presented in Sections 5.2.1 and 5.2.2 of this handbook.

8.1.2 SELECTING TRIAL SITES AND COLLECTING INPUTS AND EQUIPMENT

Almost all trials, whether FMFI tests of new equipment or complex RMRI trials, will require some input from researchers. Once trials have been designed, and formats chosen, researchers the following decisions have to be made:

(a). What should be the plot size, if plots are required? (See Section 8.2.4).

(b). What crops and varieties are to be used, and also what equipment will be needed?

(c). What number of locations will be involved, and what should be the nature of the trial sites? (See Section 8.2.1).

(d). What will be the exact inputs and equipment that will be used, and who will be the source of those inputs -- whether provided by farmers or researchers? If they are to be supplied by researchers, they need to be calculated[1] and, ordered if necessary. Supplies should be ordered as early as possible so that they are available to researchers well before the planting period.

(e). What farmers should be involved and how they should be identified? In the selection process, it is also important that researchers explain clearly to farmers the exact nature of the trial, and what will be required of them should they decide to participate. Researchers should listen to farmers' comments on the design, and be prepared to accommodate farmers' problems or interests into the final design. This

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[1]. For example, see Sections 8.3.1 and 8.3.2 on determining seed and fertilizer rates.

discussion will help farmers decide whether to participate or not.

8.1.3 MARKING PLOTS AND MAKING FINAL PREPARATIONS

Except in the case of superimposed plots, all trial plots should be marked under the supervision of research and/or field staff, and all the required inputs (e.g., seeds, equipment, etc.) must be readily available before the onset of the rains. This will be help to ensure that trials are implemented as planned and in a timely manner. For FMFI trials, researchers should also check that farmers have all the required inputs on hand before the rains. These inputs might include certain pieces of equipment, or measured amounts of seed or fertilizer.

Just before the planting season begins, researchers should review their preparations again to make sure that all the necessary inputs are in place, and that all trial plots have been marked. It is also a good idea to review trial objectives and treatments since these will have been made several months before planting. Reviewing the treatments again will help to ensure proper implementation of trials.

8.1.4 IMPLEMENTATION, DATA COLLECTION AND RECORD KEEPING

Regarding the actual implementation of the trial, and the types and methods of data collection, these will depend to a large extent on the trial objectives, design and format.

However, in all trials, it is important to keep a basic record of such items as:

(a). Names of farmer participants.
(b). Trial location.
(c). Crops and varieties involved.
(d). Dates of all operations.
(e). Relevant notes on trial observations and implementation.

Generally there is at least one book or set of data collection forms for each trial, that includes the above information, plus a map of the trial layout.

In research managed trials, in particular, it is also common to collect data on:

(a). Soil type and soil profile (see Section 8.3.3).
(b). Daily rainfall data (see Section 8.4.1).
(c). Plant population densities (see Section 8.3.4).
(d). Economic data and labor inputs (see Section 8.4.3).
(e). Grain yields (see Section 8.3.5).

There are many other types of data that researchers may wish to collect. Where researchers are not familiar with specific data collection techniques, or where the necessary equipment is not available on-farm, it is a good idea for on-farm researchers to work closely with station-based scientists. This collaboration will strengthen the on-farm research and help the station-based scientists to better understand the conditions that exist in the farm environment.

At the end of the year, when trials have been harvested and plot yields have been weighed, it is important for researchers to write-up the results as soon as possible. Such write-ups should include:

(a). Trial objectives.

(b). Justification -- that is, why the objectives were important and why the trial was necessary.

(c). Approach that was used -- that is, a description of the crops and varieties involved, plot sizes, dates of all field operations, a description of all the data collection methods used, and a list of all the data collected by plot. It is impossible to remember all of these details from year to year, so recording them immediately after completing the trial is important.

(d). Results of the data analysis, and some discussion of the researchers' interpretation of the analysis.

(e). Recommendations on future work.

8.1.5 FARMER PARTICIPATION

Where farmers are involved in trials' implementation, they should always be consulted during the design phase of the trial so as to ensure that the trials are meaningful and practical for both farmers and researchers. Researchers should also be sure to discuss farmers' observations on the trials throughout the season. In some FSR programs, it has been standard procedure to conduct formal End-of-Season Surveys to quantify and record farmers' opinions and observations on the technologies they have been involved in testing. This is a useful exercise. In most on-farm trials in Botswana, it has been a common practice to return grain yields from trials to the farmers, once the grain has been weighed. To some extent this has been done to compensate the farmers for the extra work and risks they have undertaken in implementing the trial or, in the case of RMRI trials, to compensate for the use of the land. Similarly, it is common courtesy to return the results of the trial to the participating farmers. Having observed and assisted with the trial through the year, farmers are naturally curious to know what has been discovered. It is best for farmer-researcher relations if researchers present the results of their analysis to the farmers before the next season begins.

8.2 IMPLEMENTING TRIALS

8.2.1 SELECTION OF TRIAL SITES

8.2.1.1 Criteria For Site Selection

When selecting a trial site, it is important to keep in mind that it should be:

(a). Representative of the environment that is being investigated. This representativeness is usually with reference to a specific soil type, weed complex, etc. However, on occasion, something in the human element may be taken into account, such as choosing a site that is representative of a particular soil type and is farmed by a family that has to borrow draft animals. Representativeness of a site is important so that the results obtained can be applied to other areas with similar characteristics.

(b). Relatively accessible to field staff. Sites that are not reasonably accessible are difficult to implement and monitor. Therefore such sites should be within reasonable cycling distance for field staff. This is particularly important in the case of RMRI and RMFI trials that need to be visited frequently. Inaccessible sites also make it

difficult for farmer field days to be efficiently organized.[2]

8.2.1.2 Location Of The Trial Plots Within Fields

Obviously location of a trial within a farmer's field will be determined to a great extent by the position of the physical characteristics needed (e.g., location of a particular soil type, weed complex, position on slope, high potential sites, etc.).

If the above is not a determinant of where the trial should be located within the field, then all other things being equal, it is recommended that the trial plot be located in the center of the farmer's field. The advantages of doing this, are:

(a). Farmers are more likely to apply, or have applied, their normal agricultural practices in the experimental area.
(b). Being centrally located, the trial is also potentially better protected from damage inflicted by domestic and wild animals.

Socio-cultural considerations may also influence the location of a trial. For example, it may be necessary to site the trial near the edge of the farmer's field. This can occur where there exists a strong tradition against people, other than family members, walking in the field.

All other things being equal, trials should not be located in the following spots:

(a). In corners of the fields.
(b). Under overhanging trees.
(c). On paths caused by people or livestock.
(d). On drainage channels.
(e). On slopes where run-off from activities from uphill can confound results on the trial itself, unless such relationships are the reason for the trial itself.

8.2.2 LAYING OUT FIELD PLOTS

Once the FSR team and the farmer have decided where to locate the trial in the field, decisions have to be made how to lay it out.
In RMRI and RMFI trials replications often occur in the same field. In such cases it is important to layout the trial in such a way that underlying conditions of the plots within each replication are as similar as possible. However, there can be substantial differences in these characteristics between blocks. Two obvious examples that commonly occur are:

(a). Lay blocks or replications across slopes not up and down the slope.
(b). Lay blocks or replications within a soil type, not across different soil types.

On occasion there may not be enough suitable land to locate all the plots in the same part of the field, for example, because of an overhanging tree, part of the field being prone to flooding, etc. In such a case, there is nothing wrong in physically separating the plots as long as the plots in the same block or replication are similar with reference to the underlying conditions. The key thing to bear in mind is uniformity between plots within a

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[2]. Of course, if relatively inaccessible fields have different characteristics from more accessible fields, then it is important to select some such fields if the outcome of the trial results are likely to be influenced by such differences.

block or replication, not physical proximity, that is, being all altogether in the same place. In a sense each block is like a little experiment in itself. Going from one block to another is like going from one farm to another; one doesn't expect the next farm to be the same as the first.

In FMFI trials there is no replication within fields. In these trials it is important to get the farmer to locate both the test and control plots on similar land. In other words, the two plots should be considered as being in one block, along the lines discussed above.

In order to layout the plots, some equipment is needed to undertake the exercise. Stakes or pegs and a hammer are required to mark out the plots. Also required is equipment necessary to measure the plots. Measurement of plots is the subject of the next section.

When the layout of the trial has been completed, a sketch map of the plots should be made. The overall location of the trial in the field should also be noted, particularly in the case of RMRI trials. If necessary, reference points should be indicated, e.g., huts that may exist, shade trees and any other physical features. It is also a good idea to indicate the direction of north on the map. Each plot should be numbered and have some indication as to what treatment has been assigned.

8.2.3 MEASURING FIELD AND PLOT SIZES

There are two components to measuring areas:

(a). Length of each side of the field or plot.
(b). Angle of each corner of the field or plot.

8.2.3.1 Measuring Distances

In terms of measuring distances, three of the most common methods used are as follows:

(a). ***Pacing.*** Pacing is the most inaccurate method of measurement. However, it is a quick and easy method whereby only one person is required, and no equipment is necessary. The problem with pacing is that it is difficult to standardize pace lengths which vary from individual to individual, and according to differences in ground conditions.

(b). ***Tapes And Chains.*** Each particular type of tape and chain has its disadvantages in the field. Cloth tapes are unsatisfactory in wet conditions and are liable to break at the ends. Steel tapes are prone to twisting. Chains are somewhat cumbersome to handle. Finally, at least two and usually three persons are required to measure distances using tapes or chains.

(c). ***Measuring Wheel.*** ATIP makes most use of the measuring wheel method. Only one person is required to operate the implement. However, like pacing, the accuracy of the measurement is influenced to some extent by the ground conditions.

8.2.3.2 Measuring Angles

Methods of measuring angles depend on whether or not the angle is 90 degrees. The compass is the most frequent method for measuring angles in corners of fields, where angles

can vary enormously. However, if in setting out trial plots, the aim is to have rectangular plots, then there are two other methods for measuring 90 degree angles. These are:

(a). ***The 345 Method.*** For laying out right angles without the use of a compass, the tape proves most effective. With this method, it is necessary to lay out a triangle whose sides are a proportion of 3, 4 and 5, e.g., lengths of 6 meters, 8 meters, and 10 meters.

To measure a right angle, begin from some baseline AB and a starting point labeled D on it. Measure the distance DC (e.g., 6 meters) and swing an arc on the ground called C. Next measure the distance DE (e.g., 8 meters) along baseline AB, and then from E swing another arc of an appropriate radius (e.g., 10 meters) near C, which will intersect the previous arc at that point and locate the point C. It is always desirable to check the distances to be sure that no mistakes have been made.

(b). ***The Optical Square.*** ATIP has made extensive use of an optical square for measuring right angles. This implement is very easy to use and is small enough to be put in a pocket. It is less cumbersome to use than the 345 method.

8.2.3.3 Estimating Accuracy

For rectangular plots checking the accuracy is simple enough: opposite sides should be the same length and each of the four corners should be 90 degrees.

For irregular shaped fields checking is a little more difficult. Two possible steps are as follows:

(a). ***In The Field.*** The following simple formula can be used to check whether the sum of the estimated angles approximates the total it should:

$$\frac{100 \times \text{sum of estimated angles}}{180 \times (\text{number of sides in field} - 2)}$$

If the result is less than 90 percent or more than 110 percent, then the field should be remeasured.

(b). ***In The Office.*** There are two methods that can be used in the office to further check the accuracy:

i. Draw the field to scale. If the distance between the two points that should be together is more than 10 percent of the total length of the sides, then the area of the field needs to be estimated again.

ii. Estimate the area and closing error with a specially designed program from CIMMYT which is currently only available on the Apple IIe microcomputer[3]. If the closing error is more than 10 percent, then the field should be measured again.

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[3]. This program is available from the biometric staff in DAR. See also Low and Norman [1990].

8.2.4 DECIDING ON THE PLOT SIZE

In any experimental work the size of plot required depends greatly on the objectives of the research. Generally speaking, in crops research, plots should be large enough to meet research objectives, but should not be larger than necessary. Plots which are larger than necessary will add to the time and expense of doing the experiment, but will not add any more information.

There are many factors which influence the ideal number and size of plots in an experiment. Where a researcher is not sure of the appropriate plot size it may be advisable to contact biometric staff at DAR during the trial design activities.

In the case of ATIP, the tendency has been to use fairly large plots. This has been for two main reasons:

(a). Most of the RMRI trials have been concerned with tillage systems for soil moisture conservation, or with water harvesting technologies. For these of technologies, large plots are necessary to ensure that treatment effects are separated within the experiment[4].

(b). In most RMFI and FMFI trials, part of the purpose is to examine the effect of farmer implementation of the technology. To be able to evaluate the effects of farmer implementation, farmers must have sufficient space to simulate a real operation. In other words, they must have a sufficiently large plot so that the implementation is not very much different from the way it would be done if implemented on the whole field. Where animal draft is being used, plots need to be long enough so that the animals are not constantly turning around. Also there must be sufficient space at the end of each plot for the animals to turn without entering other experimental plots.

A plot length of 40 to 50 meters and width of 10 to 15 meters has proved reasonably practical in the ATIP work. Larger plots -- up to 0.5 hectare plots -- have been used in some "systems" trials where tractors were employed. However, where larger plots are used, the total number of plots must be severely restricted, so that all plots can be planted within a reasonably short period (e.g., a day). Smaller plots have also been successfully employed for special purposes.

8.3 IMPLEMENTATION PROCEDURES

8.3.1 DETERMINING SEEDING RATES

8.3.1.1 Selecting A Desired Plant Stand

Between 1980 and 1985 the Dryland Farming Research Scheme (DLFRS) conducted a large number of trials to determine optimum plant population densities for sorghum and maize across all areas of Botswana [DLFRS, 1985]. They found that the optimum plant density for maximum grain yield was dependent upon the amount of rainfall in a given season. They also noted that most farmers preferred to reduce their risk of crop failure rather than maximize grain yields, and estimated optimum crop stand densities that would provide

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[4]. For other types of RMRI trials, sizes of plots can be similar to those usually used in trials on experiment stations.

maximum grain yields, while reducing the risk of crop failure to one year in ten or less. They presented these estimates, but with some qualifying statements. These qualifications included the opinions that:

(a). Acceptable stand densities could be in the range of plus or minus 50 percent of the estimated optimum. That is, if the estimated optimum for sorghum in an area was 50,000 plants per hectare, then acceptable stands would be in the range of 25,000 to 75,000 plants per hectare.

(b). That the estimates they provided were based on good crop husbandry (i.e., moderate fertility, and two weedings.) They suggested that under conditions of poor crop husbandry, stand densities in the lower part of the acceptable range might be preferable. For example, if 50,000 sorghum plants per hectare were recommended, then under conditions of poor husbandry 30,000 plants per hectare might be preferable.

(c). They noted that total plant population generally made a difference in grain yields, but the row width did not seem to have much of an effect. Thus the yields of plots planted with 2 meters between rows would be approximately the same as plots planted with 0.75 centimeters between rows, so long as both plots contained approximately the same total number of plants.

The optimum plant densities for maize and sorghum, determined by DLFRS, are presented for different regions of Botswana in Table 8.1.

Millet plant stand densities should probably approximate those of sorghum. However, because millet can produce many more tillers than sorghum, it can compensate for lower plant stands to a much greater degree. Thus millet stand densities at the lower end of the acceptable range for sorghum should be quite appropriate, particularly under poor crop husbandry conditions.

TABLE 8.1: RECOMMENDED SORGHUM AND MAIZE STANDS BY REGION

AREA		SORGHUM POPULATION (1000 PLANTS/HA)	MAIZE POPULATION (1000 PLANTS/HA)
Central:	Bobonong Eastward	25	10
	Mahalapye Southward	50	15
	Mmadinare	40	10
	Serowe	40	15
	Tutume	60	20
Chobe:	Whole	65	
	Northern		30
	Southern		20
Ghanzi:	North	50	15
	South	25	10
Kgalagadi		25	10
Kgatleng:	Whole	50	
	North		15
	South		20
Kweneng:	East	60	20
	West	25 - 40	15
Ngamiland		60	20
North Eastern:	Whole	60	
	Northern		20
	Southern		15
South Eastern		60	
Southern:	East	60	20
	West	25 - 40	15

Source: DLFRS [1985: pp. 65 and 67].

8.3.1.2 Determining Seed Application Rates

Once target plant stand densities have been selected, it is necessary to calculate the number of seeds to plant. During this calculation one must remember that not all of the seeds which are planted will emerge from the soil. First, it is likely that not all of the seeds in the batch are viable or alive. Even in the best seed packets, perhaps only 95 out of 100 seeds will germinate. Then, once the seeds have germinated they may be attacked by disease or insects in the soil before the plants reach the soil surface. As they emerge from the soil surface some of the plants may be killed by lack of soil moisture, by very high soil temperatures, or by pests such as grasshoppers, birds or rats. Thus the number of plants that eventually become established will be lower than the number of seeds which are planted

The percentage of planted seeds which become established can be greatly affected by management. For example, if the seeds are from the previous season, and are known to have a high percent viability (e.g., 95 percent or better), the seed has been treated with fungicide and insecticide, it is row planted near the surface in very good soil moisture, cool cloudy conditions prevail after planting, and there are very few pests around during seedling emergence, then the number of seeds which fail is likely to be quite low. However, if old, untreated seed is used, it is broadcast planted in poor soil moisture conditions, and hot sunny conditions occur after planting, then the percentage of seeds which eventually develop into crop plants may be quite low. In Botswana, it is not uncommon for the percentage of seeds which develop into crop plants to range from zero, that is, no stand, to 90 percent, depending on seed quality, management, planting method and post-planting weather conditions.

In ATIP work we have generally assumed, in farmer implemented trials, that only 30 percent of the seeds planted under broadcast conditions will survive to become seedlings, and only 50 percent under row planting conditions. Other researchers will have to use their own experience to estimate the proper percentages for their conditions.

(a). ***Broadcast Planting.*** Using the above percentage for broadcast planted plots, and assuming a final target stand density of 40,000 to 50,000 sorghum plants per hectare, the number of seeds required per hectare would be calculated as follows:

Required number of seeds/hectare =

$$\text{Required number of plants per hectare} \times \frac{100}{\%\ \text{expected to emerge}}$$

$$= 50{,}000 \times \frac{100}{30}$$

$$= 166{,}667 \text{ seeds/hectare}$$

Obviously it would take too long to count out the number of seeds to be applied per hectare. It is much more efficient to work on a weight basis, for example, to know that 3 kilograms of seed is required per hectare. It is therefore necessary to convert the number of seeds required into the weight of seeds required. This can be easily done by determining the average seed weight -- or more commonly -- the 100 seed weight.

The 100 seed weight for a seed batch can be estimated by counting out several

groups of 100 seeds each from the bulk seed that is going to be used, and getting an average weight per 100 seeds. These 100 seed weights are likely to be fairly consistent for a given crop and variety within a year, but will vary somewhat between varieties and across years. As an example, average 100 seed weights in Francistown in 1983, were 2.09 grams for sorghum (Segaolane) and 0.825 grams for millet (Serere 6A).

Once the average 100 seed weight has been determined for a seed batch, then the appropriate seed application rate for broadcast plots can be determined by the following formula:

$$\text{Weight of seed/hectare (grams)} = \text{number of seeds required} \times \frac{\text{100 seed weight}}{100}$$

Using the above example for sorghum, we get:

$$\text{Weight of seed/hectare (grams)} = 166{,}667 \text{ seeds/hectare} \times \frac{2.09 \text{ grams}}{100}$$

$$= 3{,}483 \text{ grams/hectare}$$

$$\text{Weight of seed in kg/ha} = 3.5 \text{ kg/hectare (approximately)}$$

In practice, in the Francistown area, we have used a seeding rate of 4 kilograms/hectare for Segaolane sorghum on broadcast planted plots. This has proved reasonably satisfactory for obtaining stand densities of 20,000 to 50,000 plants per hectare.

Once a seeding rate per hectare has been determined, the amount of seed to be applied on a plot -- usually less than one hectare -- can be easily calculated using the following formula.

$$\text{Amount of seed per plot (kg)} = \text{seeding rate (kg/ha)} \times \frac{\text{area of plot (sq. meters)}}{10{,}000}$$

Therefore, to apply a seeding rate of 4 kg/ha on a plot area of 10m x 40m:

$$\text{Amount of seed/plot} = 4 \text{ kg/ha} \times \frac{(10 \times 40)}{10{,}000}$$

$$= 4 \text{ kg/ha} \times \frac{400}{10{,}000}$$

$$= 0.16 \text{ kg/plot (or 160 grams/plot)}$$

In summary, to determine the weight of seed to apply on broadcast planted plots, it is first necessary to determine the target number of plants per hectare, and the percentage of seeds planted that are expected to survive. From this, the number of seeds required per hectare can be calculated. The number of seeds required per hectare is then converted to the weight of seed required per hectare. After that, the weight of seed required per plot is calculated.

(b). ***Row Planting.*** When using a row planter, it is generally easier and more accurate to

work in terms of seeds per meter of row and then in kilograms of seed per hectare. This is because most row planting machines have seed metering devices that drop seeds in the row at a fairly consistent rate. It is easier to check how many seeds the machine is dropping per meter than it is to estimate the weight of seeds the machine is dropping per hectare.

To set the planter correctly the following is necessary:

i. The desired number of seeds per meter of row is first calculated -- see below.
ii. Then the planter is set to the approximate rate and tested, usually by running it over hard ground when using animal or hand drawn planters.
iii. The number of seeds per meter coming out of the planter are counted.
iv. If the number of seeds coming out is not correct, the planter metering unit is adjusted and tested again, until the correct seeding rate is achieved.

If necessary, the weight of seed applied can be measured at planting time. To do this, the amount of seed put into the planter is first weighed. Once the relevant area has been planted, the remaining seed is removed from the planter and weighed again. The difference is the weight of seed planted.

To calculate the desired number of seeds to be planted per meter of row, complete the following steps:

i. It is first necessary to decide on the number of seeds required per hectare, for example, 100,000 seeds per hectare.

ii. From there, one of the simplest ways to proceed is to assume a hectare is 100 x 100 meters square. Then the number of rows in a hectare is:

$$= \frac{100}{\text{the distance between rows}}$$

The distance between rows is decided by the researcher.

iii. The number of seeds per row $= \dfrac{\text{the total number of seeds per hectare}}{\text{the number of rows per hectare}}$

Each row is 100m long, so the number of seeds per meter of row

$$= \frac{\text{the number of seeds per row}}{100}$$

Another simple method for determining the number of seeds per meter of row required to plant a given number of seeds per hectare is to use the information presented in Table 8.2.

8.3.2 DETERMINING FERTILIZER APPLICATION RATES

A useful **Agrifact** on fertilizer application for eastern Botswana is available from the Ministry of Agriculture (DAR, No Date). For most areas of Botswana where specific soil tests have not been done to develop fertilizer recommendations for specific fields, the above Agrifact suggests an application rate of about 20 kilograms/hectare of phosphate and 20 to 40 kilograms/hectare of nitrate (or ammonium) per hectare in years of good rainfall. It is

advisable to read the Agrifact before choosing to apply fertilizer.

TABLE 8.2: RELATIONSHIP BETWEEN SPACING AND PLANTS PER HECTARE[a]

SPACING (CMS)	PLANTS (NOS)	SPACING (CMS)	PLANTS (NOS)	SPACING (CMS)	PLANTS (NOS)	SPACING (CMS)	PLANTS (NOS)
25 x 2	2,000,000	75 x 2	666,666	100 x 40	25,000	150 x 5	133,333
25 x 5	800,000	75 x 5	266,666	100 x 50	20,000	150 x 10	66,666
25 x 10	400,000	75 x 10	133,333	100 x 60	16,666	150 x 25	26,666
25 x 15	266,666	75 x 15	88,888	100 x 75	13,333	150 x 50	13,333
25 x 20	200,000	75 x 20	66,666	100 x 80	12,500	150 x 75	8,888
25 x 25	160,000	75 x 25	53,333	100 x 90	11,111	150 x 100	6,666
		75 x 30	44,444	100 x 100	10,000	150 x 125	5,200
50 x 2	1,000,000	75 x 40	33,330			150 x 150	4,444
50 x 5	400,000	75 x 50	26,666	125 x 2	400,000		
50 x 10	200,000	75 x 60	22,222	125 x 5	160,000	150 x 5	114,280
50 x 15	133,333	75 x 75	17,777	125 x 10	80,000	150 x 10	57,140
50 x 20	100,000			125 x 20	40,000	150 x 25	22,856
50 x 25	80,000	100 x 2	500,000	125 x 25	32,000	150 x 50	11,428
50 x 30	66,666	100 x 5	200,000	125 x 30	26,666	150 x 75	7,618
50 x 35	57,142	100 x 10	100,000	125 x 40	20,000	150 x 100	5,714
50 x 40	50,000	100 x 15	66,666	125 x 50	16,000	150 x 125	4,571
50 x 45	44,444	100 x 20	50,000	125 x 60	13,333	150 x 150	3,809
50 x 50	40,000	100 x 25	40,000	125 x 75	10,400	150 x 175	3,265
		100 x 30	33,333	125 x 80	10,000		
				125 x 90	8,888		
				125 x 100	8,000		
				125 x 125	6,400		

a. 100 x 5 means rows 100cms apart with plants within rows 5cms apart.

8.3.2.1 Composition Of Fertilizers

To calculate the amount of fertilizer to apply, it is first necessary to determine the percentage of various plant nutrients in the fertilizer. This is because only part of the fertilizer in a bag is plant nutrient. The rest is made up of other materials. For example, a 50 kilogram bag of single super-phosphate contains only 5.25 kilograms of phosphate. All fertilizer bags should be clearly marked with the percentage of various plant nutrients they contain. For example, a bag of single super-phosphate should say that it contains 10.5 percent phosphate. The percentage of plant nutrients in various common fertilizers as shown in Table 8.3.

TABLE 8.3: PERCENTAGE OF PLANT NUTRIENTS IN COMMON FERTILIZERS

TYPE OF FERTILIZER	PERCENT NITROGEN	PERCENT PHOSPHATE	PERCENT POTASSIUM
Super-Phosphate	-	10.5	-
LAN	28	-	-
Ammonium Chloride	21	-	-
Urea	46	-	-
232 (22)	6	9	6
321 (25)	12	8	4

Source: DAR [No Date].

8.3.2.2 Calculating Amount Of Fertilizer Required Per Hectare

Once the amount of plant nutrient required per hectare is known, and the percentage of plant nutrient in a particular fertilizer is known, then the amount of fertilizer to be applied per hectare can be calculated as follows:

$$\text{Amount of fertilizer required per hectare} = \frac{\text{amount of plant nutrient required per hectare}}{\text{percent of plant nutrient in the fertilizer}}$$

For example, suppose a researcher wishes to apply 20 kilograms of phosphate per hectare using 232 (22) fertilizer. From Table 8.3 we know that 232 (22) fertilizer contains 9 percent phosphate. Therefore:

$$\text{Amount of fertilizer required per hectare} = \frac{20\ \text{kg/ha}}{0.09} = 222.2\ \text{kgs of fertilizer per hectare.}$$

8.3.2.3 Calculating Amount Of Fertilizer To Apply Per Plot With Broadcast Application

Once the amount of fertilizer required per hectare has been calculated, it is fairly easy to determine how much is required for an experimental plot. Note that this calculation is only useful where fertilizer is to be applied by broadcasting on the plot. This can be calculated as follows:

$$\text{Amount of fertilizer required per plot} = \text{amount of fertilizer required per hectare} \times \text{area of the plot (in hectares)}$$

For example, if a researcher wishes to apply fertilizer at the rate of 222.2 kilograms per hectare on a plot which is 10 meters x 50 meters in size, then:

$$\text{Amount of fertilizer required per plot} = 222.2\ \text{kgs/hectare} \times \frac{(10 \times 50)\ \text{m}^2\text{/plot}}{10{,}000\ \text{m}^2\text{/hectare}}$$

$$= 11.11\ \text{kgs per plot}$$

Once the amount of fertilizer required per plot has been calculated, that amount must be applied to the plot. In cases where the fertilizer is being broadcast on the plot by hand, care must be taken to spread the fertilizer evenly over the plot. This is necessary to ensure even plant growth within the plot. The normal procedure is to weigh out the correct amount of fertilizer in a bucket being careful to account for the weight of the bucket. Then the person applying the fertilizer walks over the plot spreading the fertilizer. It is best to spread too little rather than too much at first, so that all parts of the plot receive some fertilizer, and a little fertilizer is left in the bucket. The remaining fertilizer should again be spread evenly over the plot and not just dumped on one corner.

8.3.2.4 Calibrating Machines For Applying Fertilizer In Rows

To calibrate a machine so that it applies a certain amount of fertilizer per hectare in rows, it is first necessary to calculate the amount of fertilizer the machine must apply per meter of row. This is done in several steps:

(a). The amount of fertilizer to be applied per hectare is calculated as described above.
(b). The number of meters of rows in a hectare is calculated as described in Section 8.3.1.2(b) for seeding rates.
(c). Then:

$$\text{The amount of fertilizer per meter of row} = \frac{\text{amount of fertilizer required per hectare}}{\text{number of meters of rows per hectare}}$$

For example, if a researcher wishes to apply 222.2 kilograms of super-phosphate per hectare, in rows 1 meter apart, then:

Amount of fertilizer required/hectare = 222.2 kgs

The number of meters of rows/hectare

= 100 rows x 100 meters = 10,000 meters of row

Therefore:

$$\text{The amount of fertilizer required per meter (kgs)} = \frac{222.2}{10{,}000} = 0.0222 \text{ or } 22.2 \text{ grams/meter}$$

Having calculated the amount required per meter of row, the next task is to set the machine. To do this, it is first necessary to measure the circumference of the drive wheel of the machine, that is, measure the distance around the largest part of the drive wheel. This distance is the distance the machine will travel with one revolution of the wheel. For example, if the wheel measures 1.2 meters around the outside edge, then the wheel will make one complete revolution every time the machine travels 1.2 meters.

The next step is to calculate how many revolutions the wheel will make when travelling 10 meters in the row. For example, if the circumference of the wheel is 1.2 meters then in travelling 10 meters, the wheel will turn (10 ÷ 1.2) = 8.33 times.

To set the fertilizer rate, the machine is raised off the ground and a bag -- or anything to catch the fertilizer -- is placed under the area where the fertilizer comes out. The drive wheel is turned the required number of times -- in this case 8.33 turns -- and the amount of fertilizer that comes out is weighed. The metering device is adjusted and tested in this way until the machine is dispensing the required amount of fertilizer per 10 meters of row. In the above example, the machine would be adjusted until it was putting out 22.2 grams/meter times 10 meters which equals 222 grams per 8.33 turns of the wheel, that is, 10 meters of row.

This method of calibrating the machine can be used for calibrating both single and multiple row machines.

8.3.3 TAKING SOIL SAMPLES AND EXAMINING SOIL PROFILES

8.3.3.1 Soil Characterization

All farmers desire to know about the soils on their farms so that they can decide how to manage them. At present, most farmers in Botswana base these decisions on their collective, semi-empirical knowledge about the soils on their farms. For example, Botswana farmers recognize the following three major groups of soils, based on their observations of differences in the texture and color of the soils:

(a). **Seloko** -- heavy textured, dark soils (**vertisols**)
(b). **Mokata** -- medium textured, brownish soils often underlain by rocks (**luvisols**)
(c). **Motlhaba** -- light textured, reddish or pale-colored soils (**arenosols**)

However, a scientific and systematic collection of soils information could provide Botswana's farmers with better, more quantitative knowledge and understanding about the soils they cultivate. Such soils information can be obtained by:

(a). Taking soil samples from farmers' fields and later analyzing these samples for chemical and physical properties.

(b). Examining the soil profile in farmers' fields and recording these observations.

When a farmer obtains this information it can be used as the basis to:

(a). Tell how naturally productive or suitable the soil is for what he/she would like to cultivate on it.

(b). Decide what would need to be added to or to be done to the soil to make it more suitable and productive.

(c). Make sound judgments and quantitative assessments about how the soil will behave and respond to the cultivation practices or to seasonal changes. For dryland farming in Botswana, it is very important for a farmer to make quantitative assessments about the soil's moisture characteristics and availability -- specifically what will happen to the rain that falls on the soil.

8.3.3.2 Soil Sampling

The basis of a proper soil sampling technique is to ensure that the sample represents the soil in the field. Before sampling, the farmer's field should be examined for its uniformity. Observations should be made of any differences in crop growth or vegetation in various portions of the field, or of differences in texture, drainage, color, or crop condition, etc. With practice, one can rapidly judge if the entire field is uniform and, if not, to identify and delineate the uniform portions in the field. In any uniform portion, two to three locations in every hectare should be sampled. The soil taken from all locations in the portion is thoroughly mixed and a sample taken from the mix for later analysis and testing. Separate composite samples should be taken in each 10 to 15 hectares of any given uniform portion. Samples from different portions should not be mixed, as the resulting composite sample will not be representative of any portion.

If only the surface 0-15 or 0-30 centimeters of the profile is sampled, a spade or small shovel can be used to take the sample. When sampling with a spade, the soil is first excavated to the desired depth. A two to three centimeter sample slice is then cut from one side of the excavation with the spade.

If samples are needed for several depth intervals, an auger is more convenient. In Botswana, bucket-type augers are most suitable for light and medium-textured loamy sands and sandy loams. The "Dutch" or "Edelman" auger is more suitable for sampling in heavier clay soils, such as those found at Pandamatenga. Augering through stony layers requires a specially designed stone auger made out of spring steel. A special auger -- a "mud" auger -- is also necessary when sampling soils below the water table.

The date of sampling and other information to be supplied with the soil sample are usually specified by those responsible for the testing and analysis of the samples.

8.3.3.3 Examining Soil Profiles

The examination of soil profiles is usually carried out by qualified soil survey technicians.

Soil profiles can be examined by augering or by digging a soil pit. When augering, the soil

from each 20 centimeter depth interval of the profile is placed in a separate heap on the surface so that changes in the soil associated with the varying depths, can be observed.

Digging a soil pit is the preferred method for describing soil profiles. The pit is prepared in such a manner that someone can easily enter and exit, and have enough space inside to work comfortably. A pit 1 to 1.5 meters long and 0.8 to 1 meters wide is usually adequate. Generally, pits are oriented so that the sunlight simultaneously and indirectly illuminates the long sides of the pit; this implies that the long axis should be aligned approximately north/south. Pits are dug to a depth so that the parent material is exposed, but usually does not exceed 1.5 meters in depth. In deep pits, the soil is cut away to form a step or steps to assist in climbing in and out of the pit.

Once the pit is completed, the profile can be examined. Equipment needed for this task include: a knife, geologic hammer, spade, felt pen, 3 meter tape, 100 micron plastic bags, rubber bands, plastic bottle with tap water, plastic bottle with tenth normal HCl solution, a medicine dropper, clipboard, the Botswana soil profile description sheets, and a Munsell color chart.

The soil surveyor then carries out the following activities:

(a). Divides the soil profile into different layers or "horizons" based on visible soil characteristics, and assigns names to these different horizons.

(b). Describes, in detail, a set of characteristics for each horizon as set out on the profile description sheets. These characteristics are entered as codes on the sheet. A field reference card with a summary of these codes is kept on hand.

(c). Takes soil samples from each horizon for later testing and analysis.

(d). Observes and records the information regarding the landscape features surrounding the soil pit as specified in the soil profile description sheet.

Based on the recorded observations and analyses, the soil surveyor assigns a classification name to the soil profile. This name identifies which soil group the sample belongs to. The surveyor can then draw on past experience and knowledge about this group of soils to make recommendations to the farmer.

A complete methodology for soil profile examination for Botswana is detailed in a handbook produced for Botswana [Remmelzwaal and Waveren, 1988].

8.3.3.4 Assessing Soil Moisture Characteristics And Availability

As was noted above, it is important in dryland farming, in Botswana, that quantitative information about soil moisture characteristics and availability is accessible to the farmer. These data are derived from assessments made by qualified soil surveyors in consultation with the farmer.

The pathway of rainfall in dryland farming is as follows:

```
                Infiltration            Uptake              Transpiration
Rainfall-------------------------->Soil---------------------->Plant-------------------->Atmosphere
                Run-off             |                                                      ↑
                                    ---------------------->Evaporation----------------------┘
```

According to this diagram, crop growth and yield is directly proportional to the amount of water made available for transpiration in the last step of this pathway. This implies that with more infiltration and less runoff, deeper rooting systems, a greater capacity of the soil to retain moisture in the rooting depth, etc., there will be better crop growth and yield. It is thus important that the farmer understands what occurs on his/her fields after rain so as to be able to make informed decisions about how to manage the soil and crops.

The current methodology for making such assessments, based on information obtained from the soil profile examination for Botswana, is given by Rhebergen [1988: pp. 24-29].

There are two main methods to measure to measure the amount of soil moisture stored in a field at any given point in time:

(a). ***Gravimetric Method.*** In this method a 200 to 300 gram sample of the soil is dried in a forced air oven at 105°C for at least 48 hours to remove all the water. Heavy clay soils require at least 72 hours for complete drying. These soil samples are taken at several depth intervals in the field. After the first augering, the soil in the upper third of each subsequent augering should be discarded because soil from the sides of the auger hole always falls to the bottom between augerings. The soil brought up from the augerings for each depth interval is thoroughly mixed and a 200 to 300 gram sample taken and placed in a soil moisture can. These cans are designed so that no moisture can be lost from the sample after it is placed in the can. Augerings should be made at several locations in the field. The following weighings are made:

i. Weight of wet sample + can (W1)
ii. Weight of dry sample + can (W2)
iii. Weight of empty can (W3)

The gravimetric moisture content expressed as gram water per gram dry soil $= \frac{(W2 - W1)}{(W2 - W3)}$

The volumetric moisture content expressed in milliliter water per milliliter soil is obtained by multiplying the gravimetric moisture content by the dry bulk density of the soil expressed as grams of dry soil per milliliter dry soil. The dry bulk density of sandveld and hardveld soils is about 1.55. The storage in millimeters in a given depth interval is obtained by multiplying the volumetric moisture content by the depth of the interval in millimeters. The total storage in millimeters is obtained by summing the storage for each depth interval.

(b). ***Neutron Probe Method.*** The gravimetric method is destructive because once the augering is done it is not possible to sample the same locations again. The neutron probe allows the repeated measurement of soil moisture at the same locations. This method requires special knowledge in the principles and use of the probe. A useful reference on this is Gardner [1986: pp. 493-541].

The same publication also gives methods for measuring the soil dry bulk density [Blake and Hartge, 1988: pp. 363 - 375].

8.3.4 MEASURING POPULATION DENSITIES IN CROP STANDS

8.3.4.1 Purpose Of Measuring Population Density

After grain yield, plant density is the most important direct measurement in on-farm crop trials. Plant populations vary greatly among planted areas in Botswana. Different technology and other causes can influence how many of the seeds that are sown emerge and become useful plants.

The measurement needs to be made when most of the plants of the eventual crop stand are emerged and established. Establishment is a relative term, but with sorghum it is usually four to six weeks after first emergence. Established plants generally have sent roots into the sub-soil below the plowing layer.

Plant density (crop density), that is, crop stand data are used to measure a response to treatments or other effects in data analyses. Two ways to calculate stand density are:

(a). When seeding rates differ between treatments, the response should be the percentage of seed sown that emerged -- percent field emergence.

$$\text{Percent field emergence} = \frac{100 \times \text{crop stand (plants/ha)}}{\text{number seeds (seeds/ha)}}$$

(b). When a seed viability test is conducted, that is, testing the percent of seed that can germinate:

$$\text{Percent field emergence} = \frac{100 \times \text{crop stand (plants/ha)} \times \text{\% seed viable}}{\text{number seed (seeds/ha)}}$$

Population density is usually measured by researchers, not by farmers.

When it is not possible or desirable to conduct a stand count for a whole plot, it is necessary to use some sampling procedure. The systematic quadrat sampling technique is frequently used by ATIP. This method plus variants are discussed in the following sub-sections.

8.3.4.2 Systematic Quadrat Sampling For Broadcast Planting

The procedure consists of the following steps:

(a). ***Sub-Sampling.*** Sub-sample the plot with a 2 meter x 2 meter quadrat. Take 20 quadrat sub-samples in a systematic pattern. Usually, this pattern consists of two passes through the plot each with 10 equally spaced sub-samples.

Preferably, two people carry the quadrat, count plants and record data. The front carrier follows a sampling line and the rear carrier counts paces. The quadrat is placed on ground, without bias, at the toe of the rear carrier.

(b). ***Data Collection.*** In each sub-sample, count and record the number of plants of the crop.

(c). ***Calculate Crop Stand.*** This is done as follows:

$$\text{Crop stand (plants/ha)} = \frac{\text{average number plants per quadrat} \times 10{,}000}{\text{quadrat length (meters)} \times \text{quadrat width (meters)}}$$

For example, if there are an average of 8.3 sorghum plants per sub-sample and a quadrat sub-sample of 2 meters x 2 meters, the:

$$\text{Crop stand (plants/ha)} = (8.3 \times 10{,}000)/(2 \times 2)$$

$$= 20{,}750 \text{ plants/ha}$$

A microcomputer program for calculating crop stands is given elsewhere [Norman and Siebert, 1990]

When the shape of the plot is long and narrow or some other irregular shape, the sub-sampling pattern should be such that quadrat sub-samples are as equally spaced throughout the plot as is possible.

8.3.4.3 Methods For Row Planting

There are two methods for estimating crop or plant stands per hectare in row planted plots. These are discussed below.

(a). ***Systematic Quadrat Sampling.*** The procedure is as follows:

i. ***Sub-Sampling.*** Sub-sampling for row planted plots is similar to that for broadcast planting (see Section 8.3.4.2). The pattern for rows consists of two passes, each with 10 equally spaced sub-samples. Each pass follows rows near, but not on, the border. Therefore select rows that are one-fourth of the plot width from the border.

ii. ***Data Collection.*** The procedure is similar to that for broadcast plots (see Section 8.3.4.2). The main difference is that for each plot, the number of rows in the sub-sample is recorded. The number of rows sampled should remain the same for all sub-samples in a plot. When row spacing is 0.75 meters, two rows should be included in each sub-sample.

iii. ***Calculate Crop Stand.*** This is done as follows:

$$\text{Crop stand (plants/ha)} = \frac{\text{average number plants per quadrat} \times 10{,}000}{\text{number rows in quadrat} \times \text{quadrat length (meters)} \times \text{row spacing (meters)}}$$

For example, with an average of 7.4 sorghum plants per sub-sample, when each quadrat sub-sample is 2 meters x 2 meters, with an average row spacing of 0.75 meters, and two rows in the sub-sample, then the:

$$\text{Crop stand (plants/ha)} = (7.4 \times 10{,}000)/(2 \times 2 \times 0.75)$$

$$= 24{,}667 \text{ plants/ha}$$

Researchers should avoid sampling on rows where the plant stand is unusual due to a cause other than the treatment. The most common example is blockage of a planter during one pass through the plot. When this is observed, select a neighboring but not adjacent row to be sampled.

(b). ***Row Segment Measurement.*** The procedure is as follows:

i. ***Sub-Sampling.*** Sub-sampling is on segments of rows. This method is similar to the systematic quadrat method for row planting (see Section 8.3.4.3(a) above). The main difference is the use of a measuring stick, or measuring string, to mark the row segment instead of a square quadrat.

ii. ***Data Collection.*** Data collection is also similar to that of the systematic quadrat method for row planting (see Section 8.3.4.3(a) above). The segment is recorded as the length of the stick or other measuring device used.

iii. ***Calculate Crop Stand.*** This is done as follows:

$$\text{Crop stand (plants/ha)} = \frac{\text{average number plants per segment} \times 10{,}000}{\text{segment length (meters)} \times \text{row spacing (meters)}}$$

For example, with an average of 21.4 sorghum plants per segment sample, each segment having a length of 10 meters, and average row spacing of 0.75 meters, then the:

$$\text{Crop stand (plants/ha)} = (21.4 \times 10{,}000)/(10 \times 0.75)$$

$$= 28{,}633 \text{ plants/ha}$$

If more than one row is included in the segment sub-sample then:

Crop stand (plants/ha) =

$$\frac{\text{average number plants per segment} \times 10{,}000}{\text{segment length (meters)} \times \text{row spacing (meters)} \times \text{number of rows}}$$

Researchers who use this method must check that the measuring stick does not slide out of position when the counts are being made.

8.3.4.4 Methods For Mixed Cropping

Two methods can be used. They are:

(a). ***For Broadcast Mixtures.*** Use the method described for systematic quadrat sub-sampling for broadcast planting (see Section 8.3.4.2). When crops are mixed, the researcher must record the number of plants separately for each crop that is identified in a sub-sample. Crop stand is calculated for each crop in the mixture and for the combined mixture.

(b). ***For Row Planted Intercropping.*** Use the method described for row segment measurement for row planting (see Section 8.3.4.3(b)). Each crop in the intercrop is

sub-sampled and counts are recorded separately. Usually, the segment samples for one crop are paired with segment samples for the other crop. Record the proportion of intercrop rows occupied by each crop.

Stand for each crop (plants/ha) =

$$\frac{\text{average number plants per segment} \times \text{proportion of rows} \times 10{,}000}{\text{segment length (meters)} \times \text{row spacing (meters)}}$$

Stand for the intercrop (plants/ha) =

((average number plants of first crop per segment x proportion of rows) + (average number plants of second crop per segment x proportion of rows) x 10,000)) /(segment length (meters) x row spacing (meters))

For example, in a two row sorghum to one row cowpea intercrop, research staff count an average of 18.4 sorghum plants per segment sample and an average of 12.6 cowpea plants per segment sample. Each segment has a length of 8 meters. The average row spacing is 0.82 meters.

The sorghum stand (plants/ha) = 18.4 x 0.67 x 10,000)/(8 x 0.82)

= 18,699 plants/ha

The cowpea stand (plants/ha) = (12.6 x 0.33 x 10,000)/(8 x 0.82)

= 6,402 plants/ha.

The intercrop stand (plants/ha) = $\frac{((18.4 \times 0.67) + (12.6 \times 0.33) \times 10{,}000))}{(0.8 \times 0.82)}$

= 25,101 plants/ha.

Note that the inter-crop stand = the sorghum stand + the cowpea stand.

Mixed cropping situations happen in many on-farm trials. Volunteer water melons, cowpeas and so on, commonly establish in sorghum trials. In experiments controlled by the farmer, these volunteers should be left and counted. In other experiments, where agronomic data are more important, the researcher may wish to remove these plants. The removed plants are not counted.

8.3.4.5 Percent Ground Cover As An Alternative Measurement

Percent ground cover is used as an alternative to plant counts in some situations. Weed growth is often estimated by ground cover rather than by plant counts. This is because weed plants differ enormously in size per plant. Spreading crops such as water melon, pumpkin and indeterminate cowpea might also be measured on the basis of ground cover rather than plant number.

In on-farm research, percent ground cover is used to measure weed growth before plowing, weed growth at weeding time, weed growth late in the season, and water melon growth in a sorghum-melon mix.

There are two methods used. These are:

(a). ***Whole Plot Method.*** A visual estimate is made of the percent of ground covered by vegetation. The estimate is from 0 percent (no ground cover) to 100 percent (ground is completely covered). The researcher stands at one end of the plot to make the estimate. If the plot is long, the researcher divides the length into equal parts and estimates percent cover for each division of the plot. The plot estimate is the average of all division estimates.

(b). ***Quadrat Sub-Sampling Method.*** Two quadrat sub-sampling methods are used to estimate ground cover in on-farm research. For each method, 2 meter x 2 meter quadrats are used:

Method 1: The quadrats remain at fixed positions in the plot. The positions represent different parts of the plot. This method is used when repeated measures of cover are needed. Due to the time and material costs of maintenance, few fixed quadrats are used (e.g., two to four per plot). Again, a visual estimate (i.e., 0 to 100 percent) is made of the percent of ground covered by vegetation.

Method 2: The quadrats are placed for one measurement. Sub-sampling is similar to that for systematic quadrat sub-sampling for broadcast planting (see Section 8.3.4.2). The same visual estimate is made of the percent of ground cover.

Contrary to conventional wisdom, estimates of a percent cover are better than a simpler rating of cover, even if precision of the percentage seems suspect. Compare a 0 to 10 rating system with a 0 to 100 percent system. Some researchers may never differentiate better than between ratings of six or seven. But even then nothing would be lost in using percent estimates because true differentiation is still between 60 and 70 percent. Other researchers are able to differentiate better than between a six or seven rating. Particularly near the zero or ten extremes. For these researchers, the 0 to 100 percent estimate is more precise.

Accuracy, precision, and consistency between researchers will be improved with simple training on estimating percent ground cover. Even after training, ask different staff to cross check estimates on some of the same plots. Experience shows that a core of staff can be identified to give repeatable percent ground cover estimates.

8.3.5 MEASURING CROP YIELDS

Yield is the most important direct measurement in crop experiments. In this section, methods that are used to measure crop yield in on-farm research are discussed. Over the years, these methods have been used and modified to suit the needs of work in Botswana. The methods vary because requirements of experiments differ. Researchers should thoughtfully select the appropriate method for each experiment in their program.

Once a method is selected, the method should be used throughout the trial or experiment. This can ensure that differences in the data are a result of treatments and not of a change in research methods. If circumstances require a change, the change should take place between replications and not between treatments. Treatments in a replication must to be handled in a uniform manner.

Not only methods, but personnel and equipment cause bias in a yield measurement if one

treatment is favored. Farmers or staff sometimes favor a preferred treatment. When this happens, the data become biased and possibly invalid. We find that training, for staff and farmers, helps avoid bias due to uneven use of measuring methods.

The researcher will choose a method for several reasons: speed, ease, cost, information needed, precision needed, nature of crop or crop mixture, and design of the trial. The researcher must also remember that yield measurement -- by researcher or farmer -- should be handled in a way that does not greatly inconvenience the farmer.

8.3.5.1 Methods For Cereal Plots

The method used must be appropriate for cereal trials or experiments. In contrast to experiments on legumes, most cereal experiments focus on production practices. A single variety with a relatively uniform maturity, is planted. This means that yield can usually be measured with a single cutting. Plots for trials on tillage-planting and water conservation, tend to be large which increases the size of the harvest. The method also needs to be quick because cereal plots tend to be numerous in on-farm research.

All cereal trials are not the same. Some consist of a large number of plots in a field, whereas others include only two or three plots. The participation of farmers is generally more in simple experiments than in those with a larger number of plots in the field.

Three methods that are used are the following:

(a). ***Systematic Quadrat Sub-Sampling.*** The procedure, which can be used for both broadcast and row planted plots, is as follows:

i. ***Sub-Sampling.*** Sub-sample the plot with a 2 meter x 2 meter quadrat. Take 20 quadrat sub-samples in a systematic pattern. Usually, this pattern consists of two passes through the plot with 10 equally spaced sub-samples. If the plot is row planted, each pass follows rows near, but not on, the border. In such a case, select rows that are one-fourth of plot width from the border on both sides of the plot.

Preferably, three people work; two carry the quadrat and one carries the sample bags and records data. The front carrier follows a sampling line and the rear carrier counts paces. The quadrat is placed on the ground, without bias, at toe of the rear carrier. For row planting, record the number of rows in each sub-sample and average row spacing in each plot.

ii. ***Data And Sample Collection.*** In each sub-sample, counts are made on the number of plants and number of grain heads. Heads are recorded as:

HR - Heads already harvested before measurement.
MT - Heads ready for harvest.
GR - Heads which are green. These can reach maturity.
GZ - Heads which are completely missing due to livestock feeding.

At this point there are two options:

Option 1: Harvest the MT heads and put in large brown paper kraft bags. Labeling includes field, plot and quadrat number. Close and staple bags. Pack sample bags from plot in a large burlap

bag.

Option 2: Harvest the MT heads and bulk all sub-samples from the plot in a large burlap bag. This is the option now recommended.

iii. ***Drying, Threshing And Weighing Samples.*** The approach used is determined by the options used above:

Option 1: Oven dry or sun dry the sub-samples. When sun drying, the heads should be removed from the bag. A protected space is required to spread and dry the samples in the sun. Alternatively, heads may be left in the bags to dry but the bags must be fully opened. By leaving samples in the bags, drying will take a little longer but the danger of samples getting mixed up or lost is reduced.

When samples reach a uniform threshing moisture, the heads are counted, threshed, grain weighed, and data recorded on the harvest data sheet. The labeled bag is used to hold sample through the final weighing.

Option 2: If the grain is wet, dry, thresh and then weigh bulked sub-samples at the farm.

iv. ***Calculate Yield.*** Grain yield estimates, tiller number and head weights are most easily calculated by entering the data in dBase 3 Plus database package and using the program which is described in Norman and Siebert (1990).

Two additional points to note are as follows:

i. If a plot has already been harvested, collect a sample of 30 heads that were harvested in the plot. Check with the farmer with reference to this. Even if the plot is harvested, a rough estimate of yield can be made using this head sample and HR counts in the field.

ii. Other measurements can be combined with quadrat sampling, such as, plant height, visual gauging of average height of productive plants to the base of the main panicle, etc.

Systematic sub-sampling appears complicated, but experience has shown that research technicians and casual laborers can routinely and correctly handled the method. We find that a training session for technicians improves the quality of sub-sampling. When farmers harvest trials sub-sampling should not be used.

Sub-sampling is appropriate for RMRI or RMFI trials where the number of plots per field is greatest. With this method, the researcher can gather indepth agronomic information when it is needed, such as sorghum tiller numbers and head size in a RMFI Manure Trial.

Sub-sampling can more precisely estimate the effect of treatments than whole plot harvest. This is because:

i. Plot size and shape are not regular. Inaccurate estimates of plot size affect whole plot measurements, but not quadrat measurements.

ii. Non-treatment causes often mask treatment effects in portions of plots. Such visible conditions as plowing dead furrows, plot borders, water washouts, ant hills, and trees can be avoided by sub-sampling.

Harvesting by research staff can have a negative effect on the farmer's view of the trials. To help with implementation and assessment of experimental technology, researchers should strive to pass ownership of farmer implemented trials to farmers. The sense of ownership is increased if farmers harvest their own trials.

(b). ***Whole Plot Harvest.*** The procedure is as follows:

i. ***Measure Size And Shape Of Plot.*** Re-measure at the end of the season for RMRI and RMFI trials. For FMFI trials, the researcher may decide that pegging from the beginning of the season is accurate enough.

ii. ***Row Planting.*** Measure average row spacing if the plot is row planted. Average row spacing equals the width of the plot in meters divided by the number of rows in the plot.

iii. ***Plot Boundaries.*** Where they are not clear, plot boundaries need to be marked. In large plots, we find that tall sighting poles help greatly in marking boundaries. In small and intermediate size plots, string lines can be used to mark boundaries. Because the need for precise marking is less, decisions about boundaries in FMFI trials can usually be left to the host farmer.

iv. ***Farmer Harvesting.*** Discuss the needs of the trial with the farmer who will be harvesting alone. When research staff are helping with the harvest, discuss the schedule with the farmer. Arrange logistics, such as, where the harvest from the plots will be stacked for drying. If possible, researcher or field staff should visit the field on the day the farmer starts harvesting. At that time, they should label the harvest bags and agree on which bags will be used for each plot.

v. ***Harvest Criteria.*** Instruct harvesters on the criteria for harvesting, such as, whether to harvest green millet heads, heads with smut, and so on.

vi. ***Single Cutting.*** Usually plan to harvest a plot in a single cutting. If more than one cutting is planned, adjust the harvest criteria appropriately.

vii. ***Threshing And Weighing.*** After drying, thresh and weigh grain from each plot. The farmer is usually asked to transport the harvest of each plot to the threshing floor, thresh the grain and put it in a labeled bag. Bags are provided by the researchers. Identification on the bag must be simple and clear. Research staff will schedule a visit to weigh the threshed harvest from each plot.

viii. ***Calculate Yield.*** This is done as follows:

Grain yield (kg/ha) = (plot yield (kg) x 10,000)/plot size in square meters

For example, if 18 kilograms are harvested and the plot size is 10 meters x 25 meters, then:

Grain yield (kg/ha) = (18 kg x 10,000)/(10 meters x 25 meters)

= 720 kg/ha

Whole plot harvesting is easy, inexpensive, and appropriate for FMFI trials. That is why this method is recommended when farmers harvest trials alone or together with research staff. Because farmers are helping with harvesting, a much larger number of research sites can be managed. If farmers work with the harvest, they are also more likely to feel they own the trial.

The additional work required to make the whole plot method precise enough for some studies can be tedious. Plot size and shape must be accurately measured. In some instances, portions of the plot affected by causes from outside the trial[5] need to be subtracted from the plot area before calculating yield.

This method is most suitable with small and intermediate size plots. Keeping a number of large plot harvests separate is difficult and the chance of a mix-up increases.

Using this method, the researcher cannot easily collect the data to make indepth agronomic analyses. Information on tiller number and harvest plant stands would need separate sampling and measurement.

(c). ***Row Segment Measurement.*** The procedure is:

i. ***Sub-Sampling.*** Sub-sampling and data collection are similar to those of the systematic quadrat sub-sampling method (see Section 8.3.5.1(a)). The main difference is the use of a measuring stick instead of a square quadrat.

ii. ***Sample Collection.*** Cutting, drying, threshing, and weighing samples are the same as for Option 2 of systematic quadrat sub-sampling (Section 8.3.5.1(a)).

iii. ***Calculate Yield.*** Grain yield estimates, plant number, tiller number, and head weights can be calculated by entering the data into dBase 3 Plus and using a specially designed program (Norman and Siebert, 1990) or through using the following equation:

Grain yield (kg/ha) =

$$\frac{\text{(sample yield per plot (kg) x 10,000)}}{\text{(number sub-samples x segment length (meters) x row spacing (meters)}}$$

For example, if 2 kilograms are harvested from a plot, 20 segments are measured, each segment is 2 meters long, and average row spacing is 0.75 meters then:

Grain yield (kg/ha) = (2 x 10,000)/(20 x 2 x 0.75)

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[5]. For example, see the comments for systematic quadrat sub-sampling Section 8.3.5.1(a).

= 1000 kg/ha

Because this method is similar to the systematic quadrat sub-sampling method (Section 8.3.5.1(a)), most comments given in that section pertain here as well.

The use of a measuring stick, instead of a quadrat, has three effects:

i. The stick is more manageable so work can be done by two technicians instead of three.

ii. The stick is easily transported -- a big plus for staff travelling on bicycle or foot.

iii. The quadrat, however, is more decisive than the stick about defining the boundary of the sub-sample. We believe that harvest data collected with quadrats are generally more reliable than data collected with measuring sticks.

8.3.5.2 Methods For Legume Plots

Several reasons can be given why whole plot harvest is used to measure grain yield in on-farm legume trials. Three of them are:

(a). A major part of on-farm work with cowpea, mung bean and groundnut has been testing varieties and other crop comparisons. In these trials, plots can be readily distinguished by plant or seed type.

(b). Legume plots are not big, trials only include a few plots per farm, and tend to be FMFI. Farmers can readily manage the whole plot harvest of this type of trial.

(c). Most importantly, cowpea, mung bean and tepary bean have an indeterminate growth habit -- at least partially -- so that more than one harvest cutting is needed. For research staff to sub-sample a plot on a repeated basis is not practical.

Groundnut plots do not require repeated sampling. But plots are small and grain yield is more easily measured if farmers harvest whole trial plots.

Two methods that are often used for harvesting legumes are as follows:

(a). ***Systematic Quadrat Sub-Sampling.*** Systematic quadrat sub-sampling is used for measuring leaf spinach yield for crops such as cowpea. The procedure is as follows:

i. ***Sub-Sampling.*** The sub-sampling pattern is similar to that for cereals (see Section 8.3.5.1(a)).

ii. ***Data And Sample Collection.*** In each sub-sample, the number of plants are counted and leaves are harvested. Take all the leaves to measure the potential harvest. Alternatively, consult with the farmer to decide on the intensity of defoliation that is typical. Bulk or combine the sub-samples from each plot.

iii. ***Prepare Spinach And Weigh.*** Ask the farmer to prepare dried spinach and weigh.

Option 1: Weigh the plot samples while they are still fresh. Take a small sample (0.5 kilograms) from the bulked sample. Give the rest of the bulked material to the hosts to use as they please. Ask the farmer to prepare the dried spinach from the small sample. Weigh the small samples again when ready as spinach.

Option 2: Ask the farmer to prepare dried spinach from the bulked sample for each plot. Weigh it when it is ready.

iv. ***Calculate Yield.*** Depending on the option, the procedure is:

Option 1: Spinach weight per 100 square meters =

$$\frac{\text{bulked fresh sample (kg)} \times (\text{small sample fresh (kg)}/\text{small sample dried (kg)}) \times 100}{\text{plot size (square meters)}}$$

For example, if 7.4 kilograms are harvested from a 20 meters x 10 meters plot. The 0.5 kilogram small sample, when prepared as spinach, weighs 0.15 kilograms, then:

Spinach weight per 100 square meters =

$$(7.4 \times 100 \times (0.15/0.5))/(20 \times 10)$$

$$= 0.28 \text{ kg}$$

Option 2: Spinach weight per 100 square meters =

$$\frac{\text{(prepared spinach weight (kg)} \times 100)}{\text{plot size (square meters)}}$$

For example, if 0.95 kilograms spinach are prepared from leaf harvested from a 15 meters x 12 meters plot, then:

Spinach weight per 100 square meters =

$$(0.95 \times 100)/(15 \times 12) = 0.53 \text{ kg}$$

Because leaf sampling might affect grain yield, the researcher should either harvest leaf samples on parts of the plot where grain yield will not be measured, or harvest leaf samples equally on all treatments of the legume trial. If leaf sampling is only on some treatments, the others will be favored and this can bias and invalidate the yield comparison of the trial.

(b). ***Whole Plot Harvest.*** Points to note are:

i. ***Whole Plot Harvest.*** Whole plot harvest for legumes is similar to that for cereals (see Section 8.3.5.1(b)) where farmers harvest the grain.

ii. ***Cuttings.*** Because of indeterminacy in growth, more than one cutting is required to measure grain yield for cowpea, mung bean, and tepary bean. There are two approaches to dealing with cuttings:

-- Different cuttings are kept separate. If the researcher wants to compare legume treatments for each cutting, the schedule of harvesting by the farmer and weighing by research staff must be well organized. To compare correctly, farmers should harvest each treatment at each cutting, even if the yield is still small.

-- Cuttings not kept separate. For most trials, researchers can bulk the different cuttings to get one yield per plot. Even here, farmers often would like to use some of the harvest before the final harvest is completed. To help the farmers, research staff can organize a schedule of visits to check the harvesting procedure and weigh grain harvests to that date.

iii. ***Groundnut Harvest.*** Groundnut whole plot harvest is similar to that for cereals (see Section 8.3.5.1(b)), where farmers harvest the grain in one cutting. For groundnuts, grain yield is reported for the shelled -- shells removed -- harvest. Shelling percentage estimates are one of the yield quality measures for groundnut.

To obtain the groundnut shelling percentage, weigh a small sample (0.5 kilograms) of unshelled nuts which have been dried for shelling. Then shell and weigh the shelled sample.

$$\text{Shelling percentage} = \frac{(100 \times \text{weight shelled (kg)})}{\text{weight unshelled (kg)}}$$

Shelling percentage can be used to convert unshelled harvest weights to estimates of shelled weights. To get an estimate of yield when a farmer has not yet shelled his harvest: weigh the unshelled harvest, weigh a small shelling percentage sample (0.5 kilograms), shell and then re-weigh the sample.

$$\text{Shelled harvest (kg)} = \frac{\text{unshelled harvest (kg)} \times \text{shelling percentage}}{100}$$

For example, a farmer has 22 kilograms of unshelled nuts. A 0.5 kilogram sample of unshelled nuts weighs 0.24 kilograms after shelling.

Shelling percentage = (100 x 0.24)/0.50) = 48.00

Shelled harvest (kg) = (22 x 48.00)/100 = 10.56 kg

iv. ***Calculate Yield.*** Grain yield for all legumes is calculated in the same way as for cereals (see Section 8.3.5.1(b)).

Because plots in legume trials are small and the whole plot harvest method is used, estimates of yield become sensitive to errors such as overlapping treatments. Consequently it is important to discuss the requirements of a plot trial with farmers, to inspect plots, and to accurately measure plot size and grain harvest when yield estimates are important.

For groundnut, when shelled harvest weight is needed, it is best to leave the bulk of

the harvest in the shell and use the approach described under (iii) above. This is because groundnuts tend to store better in the shell.

8.3.5.3 Method For Fodder Crop Plots

Fodder yield is generally measured by systematic sub-sampling. Most fodder trials are FMFI with only a few plots on each farm. With farmers doing the work, a whole plot measurement would be preferred. But larger plots are needed to produce enough fodder so that its use pattern can be monitored. However, because fodder is bulky, weighing the entire harvest is not practical. Therefore the systematic sub-sampling method is used. Points to note about this method are the following:

i. Procedures for fodder are similar to the leaf harvest method in legumes (see Section 8.3.5.2(b)).

ii. Set the schedule for harvest measurement with the farmer. Sub-sampling must be done before the farmer harvests the remainder of the plots.

iii. Time the harvest for each fodder crop to coincide with the stage of growth when the nutritive value is optimal [ALDEP, No Date].

iv. Cut the sub-samples and immediately carry them to a safe point outside the plot. Sub-samples from one plot can be bulked together and weighed. This is a fresh weight. Fodder yield should be reported as dry weight. Spread out the bulked harvest samples for drying. Note that the recommendation for standard fodder production is to allow cut hay to dry to some extent in place. This reduces the weight and burden in transporting. Sub-samples are not heavy and removing them to a safe drying point lowers the risk of accidental loss.

v. For precise estimates of fodder yield, research staff need to weigh a sample at one week intervals beginning about two weeks after harvest. The exact beginning time is dependent on the weather conditions being conducive for drying. To manage this work, separate and weigh only a representative portion of each bulked sample that was harvested from the field. This new drying sub-sample can be put in a large burlap bag and hung to dry. A label on the bag can be used to record dates and weights. Reweigh the drying sub-sample a week later. If the weight is less than the previous weight, the sub-sample is still drying. Repeat the weighing until each drying sub-sample weight is constant. Use the constant weight as the dry weight of fodder in the sub-sample.

vi. Calculate dry matter (DM) yield as follows:

Proportion dry matter = sample dry weight (kg)/sample fresh weight (kg)

Fodder (kg DM)/harvest sample =

bulked sample (kg fresh) x proportion dry matter

$$\text{Plot fodder yield (kg DM/plot)} = \frac{\text{(fodder (kg DM) x plot size (sq. meters))}}{\text{sample size (square meters)}}$$

Fodder yield per hectare (kg DM/ha) =

$$\frac{\text{(plot fodder yield (kg DM/plot) x 10,000)}}{\text{plot size (square meters)}}$$

For example, 10 quadrat sub-samples (2 meters x 2 meters) are harvested from a plot measuring 30 meters x 30 meters The bulked fresh weight of the samples is 42 kilograms. A drying sub-sample, weighing 5 kilograms, is dried to a steady weight of 1.2 kilograms.

Proportion dry matter = 1.2/5 = 0.24.

Fodder (kg DM)/harvest sample = 42 x 0.24

= 10.08 kg DM/harvest sample

Plot fodder yield (kg DM/plot) = (10.08 x (30 x 30))/(10 x 2 x 2)

= 226.8 kg DM/plot

Fodder yield per hectare (kg DM/ha) = (226.8 x 10,000)/(30 x 30)

= 2494.8 kg DM/ha

vii. A less precise measure of fodder yield is obtained by following the procedure above with a small difference. Instead of repeatedly weighing a drying sample, allow the bulked sample to dry for a set period of six weeks or more. After this period, assume the hay is dry, return and weigh the entire bulked sample. The weight is for the harvest sample, that is, kilograms of dry matter/harvest sample.

According to research experience, fodder plots are seldom harvested at the optimal time. Researchers should be warned, if harvest is delayed much past the optimal stage, senescence and leaf drop will dramatically reduce harvest yield and harvest quality.

8.3.5.4 Method For Mixed Cropping

Mixed cropping research covers a range of trials. Trials differ in the type of growth habit and type of yield that is measured. For example, in a Sorghum-Melon Mix Study, yield measurement is for grain in sorghum and for vegetative growth in water melon. In a Sorghum-Cowpea Intercropping Trial, measurement is for grain in both crops.

Mixed cropping trials are designed to collect relatively precise agronomic data under farm conditions. Therefore, yield is measured by research staff. In the Sorghum-Melon Mix Trial, researchers use a systematic quadrat sub-sampling to measure sorghum yield (see Section 8.3.5.1(a)) together with an estimate of percent ground cover (see Section 8.3.4.5) to measure melon growth. In the row planted Sorghum-Legume Intercropping Study,

measurement is made on selected rows[6]. Yield in the Sorghum-Legume Mixed Cropping Trial is measured using the whole plot harvest method for each crop separately in the mix. These mixtures are broadcast seeded.

8.3.5.5 Method For Estimating Whole Farm Production And Average Grain Yield

Information on crop production for the whole farm can be used in descriptive and diagnostic studies of needs of farming households, inter-season variation in production, and farmer goals. Average grain yield for the farm gives a baseline value to compare with results of trials.

We use the ***Single Interview Visit Method.*** The procedure used is:

(a). Select farmers to be interviewed following completion of threshing.

(b). At an interview with the farmer -- usually about 30 minutes -- record in kilograms, or volume measures, the amount of each crop harvested in shelled/threshed terms.

(c). Ask the farmer to point out the land that was cultivated this season.

(d). Prepare a sketch of the cultivated part of the field.

(e). Measure all sides of the cultivated land with a measuring wheel. If the cultivated block has an irregular shape, divide the sketch into rectangular blocks, as large as possible. Measure the sides of these blocks[7].

(f). Calculate the land area cultivated as follows:

Area cultivated (square meters) =

average length (meters) x average width (meters) for block of land that is cultivated

If the block is irregular in shape, use the average of opposite sides as the approximate average length and width.

Cultivated land (ha) = 10,000/area cultivated (square meters)

(g). Calculate production as follows:

Farm grain production (kg threshed/shelled) =

sum of weights (kg threshed/shelled) for grain crops harvested by the farmer

The above formula implies adding together production of cereal and legume crops. Although this is not strictly correct to do, it is probably not so serious an error since the bulk of the production tends to be sorghum.

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[6]. This is similar to row segments with one row equal to the segment (see Section 8.3.5.1(c)).

[7]. See also Section 8.2.3 for alternative ways of measuring fields.

Because farmers express production in volume units, the following conversion may be helpful (see also Section 8.4.3.5):

i. Standard grain bag holds 70 kilograms of grain
ii. Standard 20 liter bucket holds 14.2 kilograms of grain

(h). Calculate the yield as follows:

Grain yield (kg threshed/shelled per hectare) =

$$\frac{\text{farm grain production (kg threshed/shelled)}}{\text{land cultivated (ha)}}$$

(i). Calculate the yield for one crop (crop A) as follows:

Use the production (kg threshed/shelled of crop A) of crop A from interview with farmer, and also identify and measure the area planted to crop A.

Yield of crop A (kg threshed/shelled crop A per hectare) =

$$\frac{\text{farm production of crop A (kg threshed/shelled)}}{\text{land cultivated with crop A (ha)}}$$

We find this type of interview to be quick and surprisingly accurate. Measuring the field takes more time than the interview, but does not require the farmer to be present. The interview is useful to estimate whole farm production, not individual plot yield. The method works well in estimating grain production of cereals, legumes, and so forth, but is less accurate for melon and spinach crop yield. Researchers would not need to notify a farmer in advance of the interview, but advanced notification is preferred. The interview obviously must follow completion of threshing and shelling.

8.4 DATA COLLECTION

8.4.1 METEOROLOGICAL DATA

Agro-meteorology is the study of weather and climate, and their relationship to all aspects of agriculture. For example, how weather and climate affects the growth, development and production of plants and animals, insect pests, and plant and animal disease pathogens. The underlying objective is to ensure that farming operations are in harmony with nature and not out of step with it [Pisani, 1981].

The daily climate record provides continuous documentation of the weather conditions under which crops are grown. For trial station purposes, the minimum requirements for weather records are usually daily measurements of rainfall, solar radiation, minimum and maximum temperatures and open pan evaporation. Some of this information and more elaborate weather data can be obtained at a regional weather station.

For FSR in Botswana the daily weather records have generally included rainfall measurements and minimum and maximum temperatures as these are easily obtained. The daily weather record can be applied to all plots that are grouped close to a rain gauge, while temperatures can be recorded at one location per village. Rainfall measurements should preferably be taken so that they refer to an area no more than 3 kilometers in diameter. In

so far as possible, rainfall records should be measured at 8 o'clock in the morning [Zandstra et al., 1981].

8.4.1.1 The Rain Gauge

This instrument is used to measure rainfall. There are many simple and cheap rain gauges which, when well maintained and cared for, can give accurate and reliable measurements. The rain gauge used by ATIP for most field work is a simple "V" collection shape which feeds rain into a holding container with graduations on the side so that the amount of rain in the gauge is easily read.

When deciding where to locate rain gauges, one has to make a judicious decision as to where to place the gauges in fields that are close together, so that one rain gauge may serve several fields. When setting rain gauges, the nearest object to the rain gauge, e.g., trees or buildings, should be at least twice as far from the gauge as the gauge is high. The gauge must be located 1.2 meters above the ground (standard), however in some cases, the gauge can be placed as high as 1.5 meters to avoid being disturbed by children and animals. The difference in the readings at the two heights is not significant. The gauges must always be kept upright and clean. Frequent checks are needed to ensure that the gauges are not leaking. Units of rainfall are recorded in millimeters.

8.4.1.2 The Thermometer

There are various types of air temperature thermometers.

(a). Maximum thermometers for measuring the highest temperature that occurs in a particular 24 hour period.
(b). Minimum thermometers for measuring the lowest temperature for a particular 24 hour period.
(c). Dry bulb thermometers used for measuring continuous temperature. When used in conjunction with a wet bulb thermometer, a dry bulb thermometer can be used to determine relative humidity.

For accurate readings, the above thermometers must be housed in a special box called the Stevenson Screen to allow in a gentle flow of air, and to prevent exposure to direct sunlight. The box must be located 1.2 meters above the ground. For most field work, locating the thermometers under a shady tree so that they are not exposed to direct sunlight will be sufficient. Locating thermometers in a house will give inaccurate readings.

8.4.1.3 Data Collection And Analysis

Simple data collection forms can be designed for recording rainfall amounts, by rain gauge, on a monthly basis. This type of form has an identification block for the rain gauge location (including a number if numbers are used), the village, the month and the year. There is then a standard calendar with space to fill in the date (done at the beginning of the month), and any rainfall that is recorded.

The rainfall data from these forms can then be entered on the Lotus 123 spreadsheet. For each rain gauge there is a daily entry which can be summed for the month and averaged for all rain gauges in a village. Summary sheets can then be prepared by rain gauge location, by village, and by research area for each month, for the cropping season, or for the year.

Temperature data can also be recorded on a simple form listing maximum and minimum temperatures by date. If relative humidity or other data are collected, the form can be expanded to include these data. The form also has an identification block for location, year and month. A spreadsheet can be used to summarize temperature data by location and season, etc.

8.4.2 DATA COLLECTION PROCEDURES

8.4.2.1 What Data Should Be Collected?

When conducting research there are numerous pieces of data which need to be collected. These data can be divided into four general types:

(a). ***Physical And Biological Environment Data.*** These type of data include many physical and biological factors which effect the trial site including weather data, soil characteristics, cropping history for the trial site, drainage patterns, etc.

(b). ***Primary Experimental Data.*** These include all measured variables from the trial such as yield data, stand counts, days to flowering, days to maturity, etc.

(c). ***Secondary Experimental Data.*** Included in this category is information which will help in interpreting the trial data such as the date of planting, the seeding rate, pest incidence, moisture stress periods, etc.

(d). ***Social, Economic And Consumption Data.*** The data set provides information essential to evaluating the potential for farmer adoption of the technology under test. The information is taken mostly from the household and local markets, and includes costs of inputs, prices which can be received for outputs, farmer reaction to the product, etc. Some data comes from the trial itself -- primarily labor data for most of our trials. Alternatively, this could be included under primary experimental data.

The data required can be collected in number of ways, i.e., by direct trial measurements, interviews with farmers, surveys conducted in the community, and/or secondary data. Perhaps one of the most important sources of data about the trial is researcher observation of the whole trial situation. These observations identify factors influencing the trial for which data have not been collected, and assist the researcher in making interpretations of the data which have been collected.

8.4.2.2 Designing Minimum Data Sets

The process of collecting data starts long before any seed is planted or any questions are asked of farmers. In order to collect data which are useful, it is necessary to decide what questions need answers. Once questions have been identified for which answers are required -- and it is best if these are stated as hypotheses -- it is possible to decide what criteria to use in evaluating the answers. Then the decision can be made as to what data needs to be collected to assess the criteria.

The choice of criteria to be used for a particular study is generally made by the research team who will be working on the study[8]. It is best if all team members participate in the decision on evaluation criteria so that all important questions are identified and the evaluation criteria which will be used in answering the questions are mutually agreed to. Even if the study is primarily agronomic in nature, it is a good idea to have ideas and agreement from team members in other disciplines.

The type and amount of data to be collected will depend on whether the trial is researcher or farmer managed, and whether it is researcher or farmer implemented. Generally the maximum amount of technical data are obtained from researcher managed and implement trials, and the maximum amount of subjective farmer assessment data are collected when the trial is farmer managed and implemented. For each type of trial, the researchers must decide how much data they can reasonably expect to collect, and how valuable the data are likely to be. There is always a question of whether too much data are being collected, or too little. We have found that, if the cost of collecting an additional piece of datum is not great, it is often worth collecting as it may add to our understanding of the results of a trial. We prefer to err on the side of collecting too much data, as it is easier to discard unneeded data than it is to go back and collect data which has been omitted.

A listing of the variables for which data should be collected is called the minimum data set, and serves as a check list of data which need to be collected for a specific trial or study. Depending on the trial objectives, this may be general data (i.e., for reporting to an international conference) or it may be very specific (i.e., for use in deciding which of two tillage systems is more profitable). It is important to decide which data must be collected to assess the criteria that have been chosen for the study. We generally integrate the minimum data sets for both the agronomic and economic parts of a trial into a single data set. For the economic studies of an agronomy trial, the data collected will generally include information on off-farm factors, such as prices of inputs and prices the farmer will receive for his/her products, the local off-farm wage rate, etc.

Once the minimum data set is determined, decisions need to be made on the types of measurements to be taken. Does data on a particular variable need to be collected by physical measurement (i.e., stop watch timing of labor activities, amount of fertilizer applied), can it be collected by farmer recall (i.e., planting date for a certain plot) or can it be obtained from a secondary source (i.e., price of grain at BAMB). The degree of accuracy of the data needed for a planned type of analysis will influence the collection method. Not all data have to be collected with the highest possible degree of accuracy. Due to the cost of collecting data, it is important to determine the degree of accuracy needed for particular types of data, and then collect the data at that level of accuracy, and not at a higher level.

Who will collect the data and when it will be collected are important questions to answer after the team has decided on the data to be collected. It must be decided if the researchers will collect the data, if field staff will collect the data, or if a special survey team will do the collecting. Also for each type of data, it must be decided if the data are to be collected:

(a). When the activity is going on, i.e., timing of planting operation.
(b). At a specific point in the study or trial, i.e., make stand counts when the plants are a certain size.
(c). Before or after field activities, i.e., soil samples taken prior to planting or prices of

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[8]. See Section 5.1.1 for a discussion of designing trials and Section 5.4 for a discussion of evaluation criteria for socio-economic research.

products determined after harvest.

8.4.2.3 Sampling Relevant Variables

After the decision has been made on which variables will be used in the study, the team must reach agreement on the size of the sample. Generally, the more variability in the variable being measured, the larger the sample size needs to be. For example, less plants must be sampled to obtain an estimate of plant height, a hereditary characteristic, than to determine something like damage from insects. Some agronomic variables which are often sampled in crop trials include; germination percentage of seeds, crop emergence, crop loss due to pests, incidence of diseases, measures of crop weediness, and harvest measures.

Table 8.4 provides some guidelines to follow when sampling particular variables. The table consists of three columns. The first column lists the general variable to be sampled, the second gives information on what and how to sample the variable, and the third provided a rough estimate of how large a given sample should be [Caldwell and Walecka, 1987: p. 288].

8.4.2.4 Design Of Data Collection Systems

When data needs are decided, the team has determined sample size, what kind of measurements are necessary, and when and by whom the data will be collected, then a data collection system consisting of forms or field book can be designed. The purpose of the data collection form or field book is to provide a convenient place to record information on relevant variables, be they activities or results, during the course of a trial. The practice of recording data directly on the data form or in the field book is a good idea. Recording data in a notebook or on pieces of paper for later transcribing to the permanent records is not recommended because there can be items overlooked if the data record is not faithfully followed, there can be errors made when the data are transcribed, and there is a temptation to add to the observations when recopying the data. There is no substitute for carefully filling in data forms at the time the data are collected in the field.

Examples of data collection forms can be found in many published studies. Also see Forms A4.1 to A4.3 in the Annex Volume [Worman, Norman and Ware-Snyder, 1990].

Most of the ATIP field book forms are pre-coded, so that transferring data from the field book to the computer is facilitated. This type of pre-coded form is a time saving feature when the data to be recorded are standard and will be similar for all forms. In some cases the forms are not pre-coded. Generally forms that are not pre-coded are used to record data for many different types of trials and often slightly different data are collected on each trial. The sheets are not normally used to directly enter data into the computer, hence the data to be entered are taken from the forms in a post-coding scheme.

Farmer evaluations of cropping trials are obtained by researcher discussion with farmers and through the use of End-of-Season Surveys. For a discussion of surveys see Chapter 7.

8.4.2.5 Recording Data

The nature of the variable usually determines when the data will be collected, i.e., before, during or after the trial. For some variables a decision needs to be made if all data for the variable will be collected or if only a sample of the data will be needed, i.e., does the entire

plot need to be harvested or can a sample be taken from the plot? Each measurement taken, whether in the field or in an interview, costs money in terms of time spent and alternative work that could be done. If there are village level staff on a project and if there has been a commitment of resources to have that staff available, then the team must decide on a set of priorities for the use of staff time among various trials and studies. The researchers will need to decide if they personally wish to collect data or if it can be collected by village staff. If it is to be collected by field staff, appropriate training must be provided. In some cases farmers may be trained to collect certain types of data.

TABLE 8.4 GUIDELINES FOR SAMPLING VARIABLES FOR AGRONOMIC STUDIES

VARIABLE TO SAMPLE	WHAT AND HOW TO SAMPLE	EST. NOS. TO SAMPLE
Viability/Germination	Remaining seed, cuttings, roots, tubers or stems	100 seeds/variety (include farmers)
Soil Sample	See Section 8.3.3	Three samples per trial site; 6 for 2 major soil types
Crop Emergence	Count emerged seedlings 1-2 weeks after emergence. Take care if replanting is a common practice	See Section 8.3.4
Lodging	Count both lodged/non-lodged plants for each treatment.	All plants in the trial; or all plants in the harvestable plot
Flowering Time	A sub-sample per variety and replicate	20 plants per variety
Plant Height	A sub-sample per variety and replicate	10 plants per variety
Foliar Insect Damage	Determine rating scale if any, to be used. Apply it at critical times during season	25 plants per plot for grains
Foliar Diseases Damage	Determine rating scale if any, to be used. Apply it at critical times during season	10 plants per plot for grains
Ear Insects	At harvest, decide on incidence, severity/or both in the harvested sample	Entire harvested sample is to be graded for disease damage incidence, severity or both
Ear Diseases	At harvest, decide on incidence, severity/or both in the harvested sample	Entire harvested sample is to be graded for disease damage incidence, severity or both
Variable Inputs	Inputs whose use is changed by the treatments. Measure quantity used in treatment and farmers' practices	All treatments and farmers' current practice, if any
Labor	Should be broken down by gender and age classes. Record time and type of task performed. Only worthwhile if the plot is large enough to simulate realistic field working conditions. See Section 8.4.3.4	All treatments and farmers' current practice, if any
Wage Rate	Ask farmers, check for government regulations, examine wage in alternative occupations (opportunity cost). See Section 11.3.2	All households involved in trials
Field Price of Inputs	Ask farmers, check government regulations, stores or merchants; when necessary be sure to add transportation costs from the purchase point to the farms (if not already done). See Section 11.3.2	All households involved in trials
Field Price of the Product (crop, livestock, etc.)	Ask farmers, check government regulations, stores or merchants; when necessary be sure to add transportation costs from the farm to the market (if not already done). See Section 11.3.2	All households involved in trials

Reference: Caldwell and Waiecka [1987: pp. 296-299].

Once data collection has begun, it is important that the researchers regularly review the field

books to ensure that the required information is being properly collected and recorded. It is also important to make photocopies of the record books once or twice during the season to ensure that data are not lost if the record book is destroyed.

8.4.2.6 Problems With Data Collection

We have encountered a number of problems with data collection. Several of these are:

(a). There is often a problem with missing observations. If an observation is missing because someone neglected to collect the data, it may be possible to collect the data at a later time. This is more often true of single point data, such as a weeding date, than it is of data collected over several days, such as weeding labor time. It is very important that field staff be reminded of the need to collect data at the designated time, and that they should contact the researcher if they will not be able to collect the data as planned. The number of missing observations can be reduced through a regular system of review for field books and data sheets.

(b). A system of review will also help to reduce the number of recording errors which is another problem we have encountered. Recording errors can be reduced through use of a good training program for village staff. In some cases recording errors can be rectified by remeasurement, such as remeasuring field size, but in others they result in lost data.

(c). We often have problems with incomplete or ambiguous data. In all cases of recording information, we stress to village staff that they should add comments if they have any questions about the data they collect. If there is some irregularity it is better to have as much information recorded as possible, so that researchers can decide on how to handle the situation.

(d). Recording labor data presents a number of problems. See Section 8.4.3.4 for a discussion of some of these problems.

8.4.3 ECONOMIC DATA

8.4.3.1 Determining Minimum Data Set[9]

When the interdisciplinary team members have decided on a study or trial and have identified objectives, they can determine what questions need to be answered. The questions that need to be answered will determine the minimum data set. For economic studies on agronomy trials, the data set may include information on off-farm factors, such as prices of inputs and prices the farmer will receive for his/her products, the local off-farm wage rate, etc.

8.4.3.2 Collecting Data

Designing survey forms is discussed in Chapter 7. Examples of survey forms and field books containing economic components can be found in the Annex Volume.

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[9]. See also Section 8.4.2.

We have found that pre-coded forms save time in entering data into computers for analysis. It is also very important for researches to check data forms that have been completed by enumerators by either doing the coding or checking enumerator coding for accuracy and inconsistencies. During data collection, supervision of enumerators is important to ensure that they do in fact understand the questions they are asking, and are recording the desired information. We have found that many enumerators lack the skills to identify and ask appropriate follow-up questions, thus researcher observation becomes most important in providing background for interpreting the data collected.

8.4.3.3 Economic Data For Agronomic Trials

What data will need to be collected depends on the trial being conducted. The types of data we collect include:

(a). ***Physical Inputs***:
- i. Amount of fertilizer used
- ii. Amount of seed used
- iii. Amount of insecticides, herbicides, etc. used

(b). ***Labor And Equipment Inputs***:
- i. Labor times by operation
- ii. Machinery time by operation
- iii. Traction time by type and operation
- iv. Transport time by type and operation

(c). ***Price Data*** (see Section 11.3.2):
- i. Wage rates
- ii. Input prices
- iii. Output prices

Not all data are collected for all trials. For example, if a variety trial is being conducted, then labor data and wage rates are probably not important -- unless, for some reason, there is expected to be a difference in labor between varieties.

The economic data needed to make an economic interpretation of an on-farm trial generally includes many factors from off-farm. The price the farmer pays for inputs and the price to be received for the output are determined by many market and policy factors, over which the farmer has no control. Thus the economic analysis usually requires collection of both on-farm and off-farm data, compared to the agronomic biological data which is collected mostly on-site.

Because price data may be common for several trials, it is useful to collect it on a regular basis. We have developed a price form (see Form A5.1 in the Annex Volume [Worman, Norman and Ware-Snyder, 1990]) which can be used to collect prices of both inputs and outputs. Some items, such as fertilizer are not included because there are generally no local village supplies, and so the price must be determined on a case-by-case basis depending on the source of supply, cost of transport, etc.

8.4.3.4 Recording Labor Data

In Botswana, labor is one of the major inputs provided by the farmer and is often an important consideration in agronomy trials.

(a). ***Reasons For Collecting Labor Data.*** Most farm families with limited resources have limited animal power, capital, etc. to invest in agriculture. Often where land is not limited the major resource farmers can invest in agriculture is labor, particularly labor that is not being used in off-farm employment. Much of the small scale arable agriculture practiced by limited resource farmers requires relatively small amounts of resources other than labor. Thus labor availability at certain times of year, i.e., during plowing or weeding, may be the major constraint a family faces in its arable agricultural activities. Hence the family's use of its labor resources is an important characteristic of the farm family, and the changes in resource allocation required by new technologies must be acceptable to the farm family if the technology is to be adopted.

There are a number of ways we have used labor data. Two of the most important are:

i. To create baseline information on how families use their labor. This involves all uses of labor including crop and livestock agriculture, off-farm employment, family maintenance activities, on-farm commercial activities (such as beer brewing), etc.

ii. As input data in evaluating the economic returns to different technologies. In this case only labor requirements which differ between the technologies need to be considered.

An important issue in both of these cases is to determine if there are labor bottlenecks which affect the farm families. The use of labor data in trial evaluations may not always indicate whether the new technology will increase or reduce bottlenecks. We can use baseline data on family labor allocations, along with labor data from trials, in an attempt to determine if the proposed technology will affect the labor constraints faced by the family.

(b). ***Labor Data Collection.*** When designing studies, trials or surveys it is important to identify what labor data are needed. Because labor data tends to be costly to collect, in terms of researcher time and effort, it is particularly important to consider what level of accuracy is needed in the labor data to be used. For example, if general indications of labor use are adequate, then it may be possible to use previously derived standard values for at least some of the operations. On the other hand, if labor differences will be critical in differentiating between two treatments, then more accurate direct measurement will be required.

There are three general approaches to labor measurement. These are:

i. The single survey approach (i.e., one short interview).
ii. The multiple interview approach.
iii. Direct measurement.

The least amount of measurement error can be expected from direct measurement, while the one-time farmer recall survey can have large measurement errors. The multiple visit approach is particularly useful in obtaining baseline information as it requires much shorter periods of recall by the farmer. This particular technique can be enhanced if farmers are provided with watches and asked to time specific activities -- assuming the farmer or a member of the family can tell the time. In some cases the multiple visit technique can be combined with a farm record keeping

system to provide better data.

Labor data collected during single interviews may include information on who is responsible for performing a task and how much time is usually spent on the task. The respondents will probably think in terms of what is routine or normally happens. In this case the labor data are collected with other data on a single data form. For multiple visit surveys, particularly ones attempting to identify major uses of labor, there may be separate sheets for agricultural labor use, for household labor use, and for other labor use, such as off-farm employment. These will be completed as often as twice a week for each participating family.

When we collect labor data in connection with a trial, the labor collection form is included in the field book for the trial and is normally completed -- often by direct measurement -- each time a trial activity takes place.

In designing labor collection forms we generally identify whether the person performing the activity is an adult or a child, and whether they are male or female. The type of operation is recorded and we record the use of any implements, such as a hoe or cultivator for weeding. An example of a trial labor data collection form is given in the Annex Volume i.e., Form A4.1 [Worman, Norman and Ware-Snyder, 1990].

(c). ***Problems With Labor Data Collection.*** We have encountered numerous problems in collecting labor data. Some of these are:

i. When deciding if labor time should be collected on an agronomy trial, and how it is to be collected, it is important to consider whether the activity takes place over a large enough field area to be considered a "normal" activity, i.e., is the time spent in the activity representative of what farmers would spend on the same activity in a non-experimental field? Very small plot sizes will not give representative labor data. We have often collected labor data in cases where the trial plots are relatively small (5 meters x 25 meters) for use in comparing treatments implemented on the same size plots. There is labor comparability between treatments in this case, but the labor data collected does not necessarily give an accurate estimate of the labor that would be required on a normal size plot using the technology. When the experimental plot size is relatively large (10 meters x 50 meters) one could introduce an adjustment factor to try and estimate the whole field labor requirement.

ii. Time is only an indicator of labor inputs. It indicates the allocation and duration of labor activities, but does not indicate the intensity of the effort required nor the economic value of the effort. Thus we can say that so many hours are spent plowing or weeding, but this does not tell us which activity requires more effort, nor which contributes more to the economic value of the crop. Also the recording of time spent in activities does not necessarily indicate their relative importance to the family.

iii. Many activities may be joint activities, such as child care and bird scaring, or bird scaring and harvesting. How the labor time spent in joint activities is divided between the activities, and how it is valued, will have a major impact in the economic value of the activity. We have generally not collected data on bird scaring because it is usually a joint activity and is difficult to value.

iv. Some researchers convert labor data to standard man-days by considering

work done by a male during a day of eight hours as a standard man-day. They then weight the time spent by females and children of different ages to convert them to man-day equivalents. Probably the most common weighing scheme in Botswana is to consider both male and female adult labor as equal to 1.0 and children above 7 and under 15 as equal to 0.5 of a man-day. Because young people can perform many tasks as well as adults (boys often do plowing and girls can bird scare as well as adults) we have used man-day conversions only for special studies.

v. One problem when collecting labor time for an activity is when to start and stop. Our general rule is to start at the beginning of the task and stop at the end, including all rest time and equipment adjustment time, unless the activity is stopped for an extended period of time due to equipment failure. If there is a great deal of time invested in equipment adjustment, as might be encountered on the first plot plowed, then this should be noted.

vi. There is a question of how much non-field time should be attributed to field operations. For example, is time going to and from the field to be counted on a particular operation? Should time spent in collecting animals be counted as part of the plowing time for a particular day? We have handled this question differently for different studies. Generally, for trials work, we have not included time traveling to or from the field, but have included normal resting time during the operation.

(d). *Estimating Labor Coefficients.* Because labor data are expensive to collect, it is sometimes possible to use standardized labor coefficients instead of direct measurements. Coefficients can be used for budget analysis and for other types of analysis when there is not expected to be a critical difference between labor inputs for a particular operation among treatments. Thus if all plowing for the treatments to be considered is done the same way, a coefficient can be used instead of an actual measurement. If however, there is a difference expected, i.e., comparing double plowing and single plowing, then direct measurements provide greater accuracy in the analysis.

Standardized labor coefficients can be estimated using labor data collected over a period of time and under different situations. These data can then be analyzed to provide coefficients for various type of labor and machine use. For example, coefficients can be derived for plowing with donkeys, cattle and tractor, for harvesting and threshing, etc. Table 8.5 suggests some standardized coefficients.

TABLE 8.5: SUGGESTED STANDARD LABOR COEFFICIENTS

OPERATION			DETAILS		
Plowing:	First	Hours/hectare	Tractor: 2.95	Oxen: 16.16	Donkeys: 26.67
	Second	Hours/hectare	Tractor: 3.10	Oxen: 15.74	Donkeys: 24.47
Planting:	Broadcast	Hours/hectare	0.90		
	Row Planting	Hours/hectare	8.15		
Harvesting:		Kgs. threshed grain/hour	Sorghum: 10.43	Millet: 5.82	
Threshing:		Kgs. grain threshed/hour	Sorghum: 9.83	Millet: 10.00	

Source: Norman, Worman and Caplan [1990].

Standardized coefficients for plowing can be based on area plowed with a fairly high degree of confidence. Likewise, harvesting and threshing are highly correlated with grain yield. The major problem we have encountered in developing standardized coefficients is in predicting weeding labor time. This is very difficult because weeding labor time depends not only on the area to be weeded but on the weed burden -- number and kind of weeds present.

8.4.3.5 Standard Units

In addition to the problems of measuring or estimating labor time, there are two other measurement problems which have to be considered:

(a). One of the areas which has been a problem for us is determining the unit of grain inputs and harvest. Many farmers do not measure their inputs or harvest in standard sized (25 or 70 kilogram bags) containers. When seed sown or harvest is measured in baskets, buckets, etc. or when items are sold by cups or baskets, it is difficult to standardize the units to be used. Thus if there is a common unit for a particular commodity, it is necessary to try and calculate an accurate standard for that unit of measure. The standard needs to be for a specific container and crop. Table 8.6 suggests some possible standard units.

TABLE 8.6: SUGGESTED CONVERSION RATIOS FOR VOLUME MEASURES

MEASURE		WEIGHT THRESHED OR SHELLED (KGS)			
		SORGHUM	MILLET	MAIZE	COWPEAS
Cup		0.30		0.31	0.29
Mug		0.45		0.46	0.44
Basin		5.31	4.35	5.00	8.00
Bucket:	Small	9.56	9.79	9.00	9.56
	Large	17.00	17.40	16.00	17.00
Basket:	Small	8.50	8.70	8.00	8.50
	Large	31.87	32.62	30.00	31.87
Sack		85.00	87.00	80.00	84.17

Source: Norman, Worman and Caplan [1990].

(b). A similar problem exists with measuring fields. In some areas there is a unit of measure called an "acre" which contains no standard amount of land but is a convenient area for plowing with oxen in a given time period, usually a day. As with the crop inputs and harvests, it is possible to measure "acres" in a village and find an average size "acre". In some parts of the country there may not be any common unit of measurement. The problem of unit of measure for land has been somewhat reduced with the extensive use of ARAP under which many fields have been measured. Thus the farmers can often give a good estimate of how big a field is as it was measured for the ARAP program. We have found that measuring field areas using a measuring wheel and compass has provided estimates of field sizes slightly lower than those used by ARAP for the same fields. This is partially due to the more accurate measurement of irregular fields possible by the wheel and compass method. Depending on how much accuracy is required, a decision on measurement technique will have to be made on a study-by-study basis. See also Section 8.2.3.

8.4.4 INTEGRATING ECONOMIC AND AGRONOMIC DATA COLLECTION

To reduce work and assure that all data relevant to a particular trial or study are maintained in the same place, we have found it important to use an integrated data collection system based on forms and/or field books for collecting all data on a trial or study, i.e., agronomic, economic, and where appropriate animal science data. By using an integrated data collection form and standard procedures, it is possible to have enumerators or other field staff collect both biological and economic data at the same time.

8.5 USEFUL REFERENCES

Section 8.2:

Section 8.2.1: Caldwell and Walecka, 1987: pp. 250-254.
Section 8.2.2: Caldwell and Walecka, 1987: pp. 254-256.
Section 8.2.3: Low and Norman, 1990.

Section 8.3:

Section 8.3.1: DLFRS, 1985: pp. 65,67.
Section 8.3.3: Blake and Hartge, 1986: pp. 363-375.
Gardner, 1986: pp. 493-541.
Remmelzwaal and Waveren, 1988.
Rhebergen, 1988: pp. 24-29.
Section 8.3.4: Caldwell and Walecka, 1987: pp. 135-137.
Section 8.3.5: Norman and Siebert, 1990.
Siebert, 1985.

Section 8.4:

Section 8.4.1: Shaner, Philipp and Schmehl, 1982: pp.321-323.
Section 8.4.2: Caldwell and Walecka, 1987: pp. 266-293.
Caldwell, Taylor and Walecka, 1987: pp. 31-37.
Shaner, Philipp and Schmehl, 1982: pp. 53-56.
Section 8.4.3: Caldwell and Walecka, 1987: pp. 77-78, 247-248.

CHAPTER 9: LIVESTOCK MONITORING AND TRIALS

This chapter contains sections on collecting livestock trial data, specific sections on identification, weighing and measuring milk off-take, and a discussion of economic analysis in livestock trials. This material is oriented towards ATIP's experience which has been primarily with small ruminants and crop/livestock interactions. A more general description of on-farm animal research involving all types of livestock can be found in Amir and Knipscheer [1989].

9.1 DATA COLLECTION

9.1.1 WHAT DATA SHOULD BE COLLECTED

The data needs for a particular trial or study are determined in a large part by the objectives of the study. There are four general objectives for on-farm animal research trials [Amir and Knipscheer, 1989, p. 104]:

(a). To verify the performance of a technology or practice that is new to local farmers.
(b). To demonstrate techniques that have been successful elsewhere where there are comparable animals production systems.
(c). To investigate results as part of a broader system, such as in a crop-livestock trial.
(d). To provide a field test for farmer acceptance of station tested technologies.

Data for animal science trials fall into four general categories [Caldwell and Walecka, 1987: p.263-264]:

(a). ***Physical And Biological Environment Data.*** Included here are physical or biological factors which affect the trial site and may include size of area available for the animals (confined or unconfined), general characteristics of the terrain, type of vegetation, etc.

(b). ***Primary Experimental Data.*** Including all measured variables such as weight, number of offspring, amount of milk offtake, weight of slaughtered animal, etc.

(c). ***Secondary Experimental Data.*** This type of information is to help interpret the primary experimental data and may include feeding frequency, disease in animals, etc.

(d). ***Social, Economic And Consumption data.*** This data provides information for evaluating the potential for farmer adoption of the system under test. It includes price data for inputs and outputs (i.e., the cost of animals for breeding, the price of milk in the market), labor data for milking, herding etc., and possibly data on taboos such as a taboo against ear tagging.

9.1.2 DETERMINING MINIMUM DATA SETS

The minimum amount of data which must be collected depends on the design of the trial and the questions for which answers are required. Once it has been decided what questions need answers, it is possible to identify the variables which will provide the necessary data to use in formulating the answers. Not only must the variables be chosen so that they will

provide the information necessary for the study, but it must be decided how the variables will be measured:

(a). Directly by physical measurement,
(b). Indirectly by farmer evaluation, or
(c). Through some type of a proxy, i.e., using the number of cattle owned by a farmer as an indication of wealth.

Many variables affecting livestock are difficult to measure in an on-farm situation. For this reason it is often best to perform more complex trials on-station, and leave the verification type of trial, which involves a few measurements and subjective evaluations by farmers, for the on-farm trials. Some of the variables that might be measured on-farm include [Amir and Knipscheer, 1989: p. 108]:

(a). ***Health***. Incidence of diseases, causes of sickness and death.
(b). ***Reproduction***. Number of animals per birth, interval between deliveries, and number of times an animal gives birth during a life cycle.
(c). ***Size Ana Growth***. Weight at birth, maturity, and slaughter and pre-weaning and post-weaning growth rates.
(d). ***Lactation***. Daily milk production and duration of lactation.
(e). ***Production Variables***. Number and weight of eggs, and type and quantity of animal traction used.
(f). ***Grazing***. Types of vegetation, nutrition, duration of grazing cycle.
(g). ***Economic***. Prices of inputs and products, costs of transportation, etc.

The minimum data set consists of all variables to be measured. Additional information can be collected if the data are readily available and the cost of collecting it is minimal. This additional data may not be used directly in the study, but may provide opportunities for subsequent analysis and/or may provide answers to questions which should have been asked, but were omitted.

It is useful to integrate the biological animal science data set with the socio-economic data set, which will be used in interpreting the biological results. By using a interdisciplinary approach to the study from the beginning there is less likelihood of lost opportunity because some significant factor was left out.

Table 9.1 provides some suggestions on the appropriate sample size for certain variables.

9.1.3 DESIGN OF DATA COLLECTION FORMS

Data must be recorded in an orderly manner. We have found that data collection forms have served well in animal science trials. If the trial involves periodic measurement of some variables (i.e., timing milking activities and recording amount milked every two weeks) then we have found a form covering each event for every participating farmer is most satisfactory. An example of this type of form, for collecting milk records from cooperators, is presented in the Annex Volume (i.e., Form A6.1 [Worman, Norman a Ware-Snyder, 1990]). When the study involves collecting daily records on some variables, we have used a form which covers a one or two week period. By using this time period it facilitates periodic checking of records and early identification of any data collection problem.

TABLE 9.1: GUIDELINES FOR SAMPLING VARIABLES FOR ANIMAL SCIENCE STUDIES

VARIABLE TO SAMPLE	WHAT AND HOW TO SAMPLE	ESTIMATED NUMBER TO SAMPLE
Milk Yield	Weigh production of each animal. For nursing dams estimate yield by weighing offspring before and after sucking	All animals in herd
	or	Will depend upon facilities and degree of variation in milk yields
	Estimate yield by weighing production from one or two quarters and extrapolate. Weighing should be done at weekly intervals	
Weight Gain	Weigh animals individually at same time daily for two consecutive days and average	Weigh all animals if numbers are small. Otherwise, select a representative sub-sample. Numbers will depend on degree of variations in body weights
	or	
	Use heart-girth measurement. Section 9.22	
	Weighing should be done at weekly intervals	
Food Intake	Weigh feed offered and subtract feed refused; conduct test for 14 consecutive days	Entire trial sample
Meat Yield	Use local grading and pricing system or some system of standard weight and quality measures	Use whole carcass of all in test
Morbidity and Mortality	Use survey techniques to determine incidence of disease and death loss	All animals in herd
Health Status	Assess severity, duration and incidence of diseases over time	All animals where number is small
Calving/Kidding Rate	Percent calf or kid crop born each year	All animals in test or as many as possible
Variable Inputs	Inputs whose use is changed by the treatments. Measure quantity used in treatment and farmers' practices (if any)	All treatments and farmers' current practice, if any
Labor	Should be broken down by gender and age classes. Record time and type of task performed.	All treatments and farmers' current practice, if any
Wage Rate	Ask farmers, check for government regulations, examine wage in alternative occupations (opportunity cost)	All households involved in trials
Field Price of Inputs	Ask farmers, check government regulations, and stores or merchants; when necessary be sure to add transportation costs from the purchase point to the farm (if not already done)	All households involved in trials
Field Price of the Product (milk, meat, eggs, etc.)	Ask farmers, check government regulations, and stores or merchants; when necessary be sure to add transportation costs from the farm to the market (if not already done)	All households involved in trials

Source: Caldwell and Waleeka [1987: pp. 296-299]

9.1.4 RECORDING DATA

In an animal science trial, the question of who is responsible for collecting data may be difficult, particularly if the data must be collected on a daily basis. Village staff are generally responsible for collecting data in a single visit study (i.e., survey data) and for periodically collecting farmer recorded data for on-going studies. Farmers may be asked to

record milking amounts, provide information on feeding, etc. If labor time is needed, it is often useful to have the village staff collect stop watch data on a periodic basis, rather than rely on farmer records or recall. It is important that all participants in a study understand who is responsible for data collection and when.

Data collection for animal science trials has a high likelihood of encountering problems. Thus it is important that research staff make regular checks on records and on the data collecting procedures. The need for this periodic monitoring is one reason why we have used single data sheets for animal science trials, rather than a field book type of data record.

9.1.5 PROBLEMS WITH DATA COLLECTION

One of the major problems we have faced with data collection in animal trials is assuring the timeliness of data collection. Data collection for many variables must be done on a daily basis, including holidays and weekends. This has created staff problems and is one of the reasons why animal science trials, involving a high degree of accuracy, can best be done on-station rather than on-farm. It is important for researchers to know which data must be collected in a timely manner, and which data are collectable over a period of several days, and communicate this to the individuals responsible for data collection. Very often data missed through lack of timeliness in collection are data which cannot be replaced.

Other reasons for missing data which are common in animal science work are the missed observation because an animal has strayed, or the loss of data when an animal is sold or dies during a study. Well designed trials, staff training, and close supervision can all help to reduce missing data problems.

9.2 PROCEDURES

9.2.1 IDENTIFICATION

Many animal science studies follow a relatively few number of animals over a period of time lasting from several weeks to several years. Generally these studies require records on individual animals, so it is important to be able to identify specific animals each time data are collected.

There are numerous methods for identifying animals. The most common methods for identifying small stock and large animals are:

(a). Ear marking which includes ear notching, ear tattooing and ear tagging
(b). Branding
(c). Paint branding
(d). Paint stick marking
(e). Neck tags
(f). Visual identification (name) - usually used when only a few animals are involved.

Below are listed several suggestions, based on ATIP experience, for facilitating the process of identifying small stock, particularly goats:

(a). Before going out to the village to do the actual identification, be sure to make appointments with the farmers so that they keep their animals penned until you arrive. Alternatively, one can leave very early in the morning to arrive before the animals are turned out.

(b). If identification is by ear tag, have the following equipment on hand:

i. Tagging Pliers -- a device used to make a permanent hole in the animal's ear and place the tag in one operation.
ii. Tags -- come in two parts, the male part of the tag with a peg and the female part with a hole.
iii. Information Forms -- to keep a record of the herd.

(c). When tagging the goat, hold the goat tightly by the horns or by the head so that it doesn't move. Pay attention that you don't punch in the veins, but in between them. The goats ear doesn't usually need to be washed. The tag should be placed high up into the ear to reduce the possibility of its ripping out.

(d). Each farmer's herd should have a different color tag.

(e). After giving the goat a number, record it's sex, age, and whatever farmer identification is necessary. The age is determined by looking at the teeth. A kid will have small teeth. A one year old goat will have one set of two teeth in the bottom front. A two year old goat will have two sets of two teeth. A three year old goat will have three sets of two teeth. A four year old goat will have eight relatively large lower incisor teeth. That is because the teeth have begun wearing down. The age of that goat is listed as four. Any goat older than four years is given the age of four plus. Goats' teeth will go through various stages after the wear stage. There is the spreader stage, where the teeth because they have worn down so much, now appear to be separated. Broken mouth is the last stage, where the teeth are broken, worn down, and separated. All of these stages are considered four plus.

9.2.2 ESTIMATING WEIGHTS

There are two basic ways of determining animal weights. These are:

(a). Physically measure the weight using a scale. This is relatively easy with small animals, such as chickens. is more difficult with small stock such as goats or sheep, and without special equipment, is impossible for large animals such as cattle. Special types of scales are available for weighing large animals, but they are difficult to move and so are not practical for on-farm measurements.

(b). Estimate the weight by using a tape measure to measure the heart-girth and then a table to find the corresponding weight for that heart-girth. There are measuring tapes for some breeds of cattle which are directly calibrated to weight, so that a table is not needed. If a table has been developed for the particular species of livestock you wish to weigh, the use of the heart-girth measurement is the easiest method of estimating weight, particularly for such activities as dosing animals where exact weight measurements are not critical.

The following are some suggestions for weighing goats derived from ATIP's experience.

(a). Take the following pieces of equipment with you when you go to weigh:

i. A 100kg scale with 1kg increments.
ii. A bag with four holes punched in it, and a rope or cord through the holes so

that bag can be hung up.

iii. A tripod with a hook hanging from the middle.

iv. A book or a record form to record the weights.

(b). Make sure the goats are kept in the **kraal** until you weigh them. After you weigh them you let them out of the **kraal**. That way you know which goats you have weighed. Marking the goats with marking chalk as they are handled will also identify animals which have been weighed. In order to find the goats still in their kraal, you must go to the field very early, around 6 to 6.30am. One of the major sources of variation in animal weights is determined by "gut fill" or how much the animal has eaten or drunk. By weighing animals early in the morning, before they have gone for water or started to forage, the problem of differences due to different amounts of eating and drinking can be reduced.

(c). Set up the tripod. Hook the scale from the top of the tripod. Lay the bag flat on the ground. Turn the goat upside down, so that it is lying on its back in the bag. Two people are needed to lift the bag with the goat inside. Hang the bag on the scale. Read the weight and record in your notebook or on the form. Be sure to record the tag number or other identification.

(d). Some goats may have lost their tags since the last tagging. This is a problem with tags and, unless the animals have been tattooed or otherwise marked, it will be impossible to correlate the old tag number with a new tag number even if the goats are re-tagged during the weighing. Thus data will be lost for those animals.

(e). If weights are to be estimated using a heart-girth measurement, the animals must be caught and measured just behind the shoulders. The measurement, in centimeters, is recorded on the appropriate data form and is later converted to a weight measure using a conversion table. The animal is then marked as having been measured and released. From experimental data in the Tutume Agricultural District, ATIP has created a heart-girth weight conversion table for goats. This is given in Table 9.2.

9.2.3 MEASURING MILK OFFTAKE

Because of its economic importance and social value to the small farmer, milk production is often one of the variables to be measured in a trial. Milk yield is relatively simple to measure unless there are nursing calves or kids. If there are nursing calves or kids it is possible to estimate milk production by milking the animal after it has been separated from the offspring for at least eight hours.

FMFI and RMFI animal trials run by ATIP which involve milk offtake. have generally had the farmer responsible for milking and recording the amount of milk taken. For RMRI trials the village staff have been responsible for milking and recording the data. Below are some observations on recording milk offtake.

(a). When the farmer is responsible for milking goats and for recording the offtake, the researcher has the responsibility to train the farmer how to read the measuring container and how to record the milk offtake.

(b). The milk is measured with a one-liter measuring cup (with 50 ml increments). Each farmer is given one measuring cup and a data form -- see Annex Volume for example -- for recording the milk offtake.

(c). The milking goats are tagged. Each goat's milk is recorded separately on the form. The farmers are to record the milk offtake whenever they milk. Some farmers may milk twice a day and some only once a day. If the goats have gone astray, it is difficult to keep an accurate record.

(d). For most milking studies, goats are milked for at least one lactation period.

(e). Village staff should collect the milk record forms periodically -- once a week for daily records or immediately after recording for milkings recorded only occasionally.

TABLE 9.2: ESTIMATED WEIGHTS FOR TSWANA GOATS BASED ON HEART-GIRTH MEASUREMENTS, TUTUME AGRICULTURAL DISTRICT, 1989

HEART GIRTH CM	0 TO 3 MONTHS WEIGHT KG	GOATS OVER 3 MONTHS FEMALE WEIGHT KG	MALE WEIGHT KG	MALE/CAST WEIGHT KG
25	1.8			
26	1.9			
27	2.1			
28	2.2			
29	2.4			
30	2.6			
31	2.9			
32	3.2			
33	3.6			
34	3.9			
35	4.2			
36	4.5			
37	4.8			
38	5.1			
39	5.4			
40	5.7			
41	6.0			
42	6.3	6.7	9.7	8.8
43	6.6	7.3	10.0	9.1
44	7.4	7.9	10.3	9.4
45	7.9	8.5	10.7	9.7
46	8.3	9.2	11.0	10.0
47	8.7	9.8	11.4	10.3
48	9.1	10.5	11.8	10.7
49	9.5	11.2	12.3	11.1
50	10.0	11.9	12.7	11.6
51	10.4	12.6	13.2	12.0
52		13.3	13.7	12.5
53		14.0	14.3	13.1
54		14.8	14.9	13.6
55		15.5	15.5	14.2
56		16.3	16.1	14.8
57		17.1	16.7	15.4
57		17.1	16.7	15.4
58		17.9	17.4	16.1
59		18.7	18.1	16.8
60		19.6	18.8	17.5
61		20.4	19.6	18.2
62		21.3	21.4	19.0
63		22.3	21.2	19.8
64		23.0	22.0	20.7
65		23.9	22.8	21.5
66		24.9	23.7	22.4
67		25.8	24.6	23.3
68		26.7	25.6	24.3
69		27.7	26.5	25.2
70		28.7	27.5	26.2
71		29.7	28.5	27.5
72		30.7	29.6	28.3
73		31.7	30.6	29.4
74		32.7	31.7	30.5
75		33.7	32.8	31.6
76		34.8	34.0	32.8
77		35.9	35.1	34.0
78		37.0	36.3	35.2
79		38.1	37.6	36.5
80		39.2	38.8	37.8
81		40.3	40.1	39.1
82		41.4	41.4	40.4
83		42.6	42.7	41.8
84		43.8	44.0	43.2
85		44.9	45.4	44.6
86		46.1	46.8	46.0
87		47.4	48.3	47.5
88		48.6	49.7	49.0

Source: Thedford, Worman, Kelemogile and Baathodi [1990].

9.3 ECONOMIC COMPONENTS OF ANIMAL SCIENCE TRIALS

There are two general types of economic studies associated with animal science trials. These are:

(a). The economic evaluation of a particular on-farm animal trial to ascertain if the technology is economically feasible, and to give some general indication of the economic value of the technology to farmers.

(b). The second type of evaluation is more descriptive in nature and is aimed at

identifying and monitoring the livestock component of a farming system. This type of study usually involves tracing changes in the farm's livestock component over time, based in part on periodic inventories.

There are a number of types of data which may need to be collected in order to evaluate livestock trials. These include:

(a). Feed information: quantity and type.
(b). Labor data: time, activity, and information on person doing the labor, i.e., sex, age, household or non-household member.
(c). Inputs other than feed: medicines, etc.
(d). Outputs: meat, milk, eggs, manure, traction, etc.
(e). Price information on inputs and outputs.
(f). Inventory data: type and number of animals owned.
(g). Management practices: feeding, watering, marketing, etc.

9.3.1 ECONOMIC EVALUATION OF ON-FARM ANIMAL TRIALS

What economic data will need to be collected for evaluating the economic potential of an on-farm animal trial will depend on the trial. Part or most of the data listed above may be needed. For example, if different management practices are involved, labor data will probably be needed. Prices, and sometimes other factors, are determined by the market for the inputs or outputs and are often influenced by government policies, all of which are outside the individual farmer's control. Thus much of the data needed for economic analysis is collected off-farm, while the data for the biological analysis is collected on-farm.

We have used a general price survey form for collecting information on the selling price of livestock. In addition we have used a form for collecting data on livestock sales to restaurants in a village. Both of these forms may be found in the Annex Volume (i.e., Forms A5.1 and A5.3 [Worman, Norman and Ware-Snyder, 1990]].

9.3.2 BASELINE AND MONITORING STUDIES

Information collected for baseline and monitoring studies can include data on labor used in the livestock enterprises, what types of inputs are used, management practices, etc. One of the major components of this type of study is usually an inventory of livestock owned within the farming system. Inventories may be a one-time survey, as in a baseline study, or may be done periodically, i.e., on a quarterly or yearly basis (e.g., Forms A6.3 and A6.4 [Worman, Norman and Ware-Snyder, 1990]). The data collected usually consists of number of animals owned by type, age, sex, etc. Example inventory forms are included in the Annex Volume. If more precise information is needed on the changes in farm livestock, a regular (weekly to monthly) inventory change form can be used to record births, deaths, sales, purchases, etc.

We have found that livestock inventory data are sometimes of questionable accuracy. This may be because individuals do not wish to disclose the actual number of animals they own, or they may not know -- particularly in the case of large herds kept at distant cattle posts and visited infrequently by the owners. In addition, when compiling records of livestock changes, the usual method is to use farmer recall data. Farmers tend to recall some events, (i.e., cattle births), but not remember other less significant events (i.e., the loss of a chick to a hawk). Thus data on larger animals and animals that are few in number are probably more accurate than data on small animals and large herds or flocks.

9.4 USEFUL REFERENCES

Section 9.1:

Caldwell and Walecka, 1987: pp. 256-259, 263-264.
Shaner, Philipp and Schmehl, 1982.

Section 9.2:

Bernsten, Fitzhugh and Knipscheer, 1984.
Zandstra, 1985.

PART FOUR:

ANALYTICAL PROCEDURES

CHAPTER 10: DATA MANAGEMENT

Data management is an increasingly important part of any research program. This chapter discusses various aspects of data management using microcomputers. The chapter is primarily written for researchers who will be using IBM compatible computers and programs. The basic concepts are applicable to all computer systems, i.e., Apple systems, but some of the specifics on programs will be different. The final section identifies some of the computer programs commonly used in farming systems research.

10.1 WHAT IS DATA MANAGEMENT?

Data management is the activity of rapidly organizing, recording, and storing collected research data in a form that is suitable for analysis, while minimizing the chance of data errors. Many farming systems teams collect large amounts of data. The collection of data may become an end in itself, but to be effective, data must be analyzed and reported in a form which is useful to a decision maker, whether that person is a farmer, a policy maker, an extension agent, or another researcher.

Data processing techniques and equipment, as well as analysis procedures, have developed rapidly in the last five years. Today microcomputers are available in many locations and are locally available to farming systems teams who in the past had to rely on facilities in major cities for any computer services. This means that more members of farming systems teams can be involved in data management and analysis than ever before.

The fact that data management and analysis can be done by FS researchers working in relatively remote locations is a major advance, as these researchers are responsible for collecting data and so are in the best position to evaluate the implications of the data.

Data management begins before data collection, when the team decides what type of analyses will be performed on the data. The amount and type of data, and the proposed analysis will affect the way data are collected and stored for further analysis. Data management generally includes the following steps:

(a). Design of data collection forms which allow all relevant data to be collected in a single document or set of documents.

(b). Data collection forms are most useful when designed to allow for rapid coding of information and direct entry from the forms to a computer.

(c). Data must be coded using a system that retains the integrity and value of the data, and is compatible with the form of storage and processing to be used (i.e., electronic data processing by computer).

(d). It is a good idea to keep related data together on the forms, and in the database created. This will allow more rapid data entry and facilitates hand tabulations for preliminary analyses.

(e). Once data forms are coded and data checked for inconsistencies and errors, the data are entered into a database (i.e., some type of computer program).

(f). Data which have been entered into a database should be checked to make sure that data entry errors are eliminated or reduced as much as possible.

(g). At this point the data are ready for analysis.

(h). A final very important step is the documentation of the data. The data should be documented in such a way that future researchers can decide if the data are relevant to their needs, and if so, they must have sufficient documentation to allow them to retrieve the data from the database and use it effectively for their research purposes.

Good data management is a vital part of any good research program. It is the building block for accurate analysis and high quality publications. It is important to remember that a computer is a very accurate but a very dumb machine. It will do exactly what it is told with the data that have been entered. The computer cannot think, so it can not identify and correct data errors. Whether a computer is a superior research tool or makes a complete mess of a research program depends on the researcher. A computer is a "gigo" system, that is, "garbage in - garbage out". Results will only be as good as the data that are put into the system.

10.2 STRUCTURING DATABASES

10.2.1 WHAT IS A DATABASE?

A database is an organized collection of related information. Databases are used every day, such as an address book, the phone book, or a savings book. Each of these databases organizes the information (or data) in such a way that it is easy to retrieve.

A simple database may be a listing of information on individual farmers for a village. This information could be listed on a sheet of paper, be listed on a group of cards with one card per farmer, or be entered into a computer database. The same information can be entered in all of these data storage systems. An example of such data could be:

Farmer Name	Farmer Number	Number of Cattle	Uses Cattle to Plow
Tibone	62.01	125	Yes
Masikara	62.02	35	Yes
Worman	62.03	2	No

In a database file, each particular entry is called a record, (i.e., all the information on farmer Tibone). Each item of information within a record (i.e., Farmer Name) is called a field and contains information on one variable (i.e., the farmer's name). In an address book, a friend's name is a field, their post office box number would be a field, and their village would be a field. All of these fields together make a record. There maybe from one or two to more than 100 fields or variables in a database. In the same way a database may contain only five or ten records, or it may contain several thousand.

The above information is a database whether it is written on a sheet of paper, written on cards (with one farmer per card), or stored in a computer with a file name (e.g., Farmer.dat). The type of database storage chosen will depend on the use to be made of the information. If there are few records and few variables, a listing on a sheet of paper may be sufficient. If there is only a need to count the number of farmers doing something, the data collection form -- a sheet of paper with all farmers listed, or one form per farmer -- may be sufficient for storage of the data. However, for most situations in farming systems research where

there are a number of variables and/or cases involved, and when analysis will include the use of statistical or other mathematical procedures, it is usually worth the time to create a computer database. In some situations the data are best entered into a database using a database program such as dBase III Plus. This type of program is particularly advantageous when there are a large number of cases and/or variables to be entered. In other situations, such as when there are few cases and variables, it may be faster and easier to enter the data directly into the program to be used for analysis (i.e., direct data entry into a spread sheet such as Lotus 123).

10.2.2 CREATING A DATABASE

Creating a database on a computer is a simple task when you follow the guidelines. Note that all computer programs require some type of structure for entering data; in some cases the user defines the structure, in others the structure is pre-defined and the user can modify it.

Before data can be put into a database file, its structure must be defined. This structure is really an empty grid consisting of rows (records or cases) and columns (fields or variables). Once the computer has been given information on the structure of a database, data can be entered to create the complete database. The basis for defining the structure is providing information on the fields.

(a). Every field must be assigned the following:

i. ***Field Name.*** This should be appropriate (help to identify the variable in the field) and unique. Most database software will have restrictions on the size of the name. One to eight letters are the most common.

ii. ***Field Type.*** The most common types are character and numeric. It is sometimes difficult deciding if a field type should be character or numeric. Here are some tips:

-- A character type should be given to any field that will contain letters, numbers, and punctuation.
-- A numeric type should be given to any field that contains only numeric data and will be used in doing calculations.

iii. ***Field Width.*** The width can be any appropriate length. If you are having trouble deciding on the width, think of the longest entries that you could possibly have for this field and give it that width. Having just said that, keep in mind that the larger a field, the more space the database will take up in the computer.

(b). Keep a copy of your structure definition list while you are creating other parts of your database. It is also good to keep this handy for others who use your database.

(c). Enter the structure definition list into the computer. Each database software has a different name for this step. In dBase III Plus it is called the Database File Structure. If the field names are entered in the same order that the variables are encountered on the data form it will make data entry easier.

(d). For more information concerning structuring databases, see the manuals for the database software you are using.

(e). If more than one database file is to be created from a data set, and if you will want to combine the databases during analysis, it is very important to have a common identification variable, i.e., "DVDU" (district, village, dwelling unit number), in each database file so that it can be used as a reference for combining the records from different database files[1].

10.3 CODING DATA

10.3.1 WHAT IS CODING?

Coding is the process of taking information collected in surveys or through trials and categorizing it so that it may be used in computations. Generally data can be divided into two classes, quantitative and qualitative. Quantitative data are the type which can be represented numerically, i.e., number of head of cattle, age, kilograms of yield, etc. This type of data are easily coded, by use of the number. Qualitative data (data presented in words), on the other hand, tends to be based on individual opinion or observation, and are generally not numeric in nature. Examples would be: whether one variety appears to be more vigorous than another, the reason for crop failure, whether a farmer intends to sell some of his crop, etc.

Data that are numerical in nature are easily coded by using the number. In some cases it is desirable to aggregate the data into categories, i.e., categorize farmers by the number of cattle they own, where ownership categories involve a range of cattle: no cattle, 1-15 head, etc. In this case each category is assigned a number.

Qualitative data are usually coded by assigning a number to a particular answer (e.g., yes=1, no=2), or to a group of answers (e.g., answers where any kind of insect pest is identified as a problem are coded as "1"). While qualitative data can be entered as character data, it is highly desirable to have them coded and entered as numeric data, as numeric data are much easier to handle during computations than are character data.

Researchers must decide when coding will be done, and by whom. We have tended to use a questionnaire format which has pre-coded answers to questions, where the answers are identified with specific coding numbers. For example:

_____ Yes (1) _____ No (2) PLNT_____

There is a coding strip on the right hand side of the page where the variable name to be used in the database is given and a space is left for the appropriate code.

In cases where there is an open-ended question, or an "other" category, the answers must be post-coded in the sense that after the survey is administered the responses are grouped into categories and given an individual code number, which is entered in the coding strip on the right side of the page.

This type of field recording form is not a true pre-coded form, which is one where all possible answers are included and the enumerator only has to blacken the square (i.e., answer forms used for standardized testing), nor is it a completely non-coded form that requires a separate data coding sheet which is filled in from the original field notes or

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[1]. See also discussion on designing questionnaires in Section 7.3.3. Much of the material in that section also relates to material presented in Section 10.3.

forms, coded, and then used for data entry. The intermediate type of form we use generally allows direct coding on the form and data entry from this form. Thus we have only one record (be it one sheet or a field book) for each case.

10.3.2 EXAMPLES OF CODING

The following are some examples of coding approaches taken from surveys done by ATIP staff.

(a). A chart or grid form can be coded by giving each square a unique variable name. For example; 1BORN, 2BORN, 3BORN where 1, 2, and 3 indicate the month. It is also possible to enter the data into the computer in this grid form. It depends on how the data are going to be analyzed. If the data are all quantitative numeric data it can be entered without specific coding. Data are entered directly and does not need further coding.

(b). Another type of coding scheme is where data are recorded and then entered in a coding column on the right hand side of the page. The coding in this case can be done by the enumerator in the field, or later by the researcher.

There are a number of ways that coding information can be included in the questionnaire itself. For items which are to be post coded, a coding sheet or book must be produced which indicates the codes for particular questions. It is usually a good idea to include codes for all of the questions on the sheet or book, so that later the data may be used without having to refer to the original data collection sheet. In other words, the researcher should note what each response category means for each variable.

(c). For some data collection we use forms that do not contain any coding information. These forms are usually for recording field activities and other data which will not be transferred to a database. The few items that may be used from this type of form are identified through post-recording by the researcher and are either transferred to a data sheet or directly entered. In some cases a survey, such as an End-of-Season Survey, may be used to collect data on the same activity, and which is then cross-checked with the field data form.

10.3.3 SOME PRACTICAL SUGGESTIONS ON CODING

When coding data there are several things that are useful to remember:

(a). Coding should always be checked. If coding is done by field workers, the coding should be checked by the researcher. If the researcher does the coding, then someone else should review that coding. This will help reduce coding errors. When the researcher is doing the coding, or checking someone elses coding, it is a good time to look for inconsistent data (i.e., data outside expected values).

(b). How missing data are to be coded should be decided before coding begins and must be consistent for all variables. It must be decided how to code cases where no answer is expected, i.e., in the case where a crop was not planted we do not expect to have a yield reported. In the context of the data, does this need to be coded differently from a yield which is "0" or one which is missing? It is tempting to leave missing data as a blank. This can be a problem when data are transferred

between programs as some programs will read a blank as a zero rather than as a blank. It is generally a good strategy to code missing data as "99" or "999", which can then be changed to a missing data identifier for the particular statistics program to be used to analyze the data.

(c). When creating field names for the variables it is best to limit the name to four or six letters/numbers as some programs do not recognize field (variable) names over six characters long. Thus, if names are used that are eight or more characters in length, as can be done with programs like dBase III Plus, and then the data are transferred to a program which allows only six characters, like Abstat, there can be confusion when two variables have the first six characters in common. In this case only the first field will be read and we end up wondering what happened to our other variable.

(d). Variable or field names are most useful if they reflect what the data are about. For example, "PLWDT" may remind us of plowing date. Programs will not allow the use of the same name for more than one variable.

(e). As mentioned earlier, when coding qualitative or non-numeric information it is very important to use codes that are numbers and not characters or mixtures of characters and numbers. Some statistical packages (e.g., Abstat) and routines do not handle character data for some applications, and it may be necessary to go back and recode some data to be able to complete a wanted statistical test. Thus, unless a variable is all character in nature (i.e., a farmer's name), it is best to enter it as a numerical rather than a character variable.

(f). It is better to code a true-false question as a numeric (i.e., 1 or 2) rather than as a binomial (i.e., true or not true). This is because some statistical programs do not handle data presented in this fashion, even though the database program allows it. The general rule is to use numeric fields and numeric codes when at all practical.

10.4 DATA ENTRY AND CHECKING

10.4.1 METHODS OF DATA ENTRY

While data can be entered into the computer in several ways, the easiest way for most people to do it is by direct entry from the data forms into a computer program, either a database program or some other type of program (i.e., Lotus 123). Data may be entered from a coded data form directly into the previously defined data structure of a program as long as the data are in the same format for each record, and the variables in each record are in the same order as the fields in the program. If this is not the case it may be easier to create a ***screen format*** or ***entry format*** mimicking the data collection form. Such a format allows the data entry person to record the data in the same order as it was collected. In either case it is most efficient to have the data entered starting at the beginning of the data entry form and entering the data in the order it appears on the form. Doing it any other way necessitates the data entry person turning pages all the time. It takes much longer to enter the data and increases the risk of making data entry errors.

10.4.2 THE WHO AND WHEN OF DATA ENTRY

With a well designed and coded form, and using a microcomputer with a standard type of database program, almost anyone with minimal typing and computer skills can enter data.

On the other hand, if the data have been poorly coded, are in a confusing format, or have not been edited to correct errors; then it will take the researcher considerable time to enter the data as she/he must "clean" the data before entering it. This points out the importance of using forms that are clear and not cluttered, the need for thorough coding and checking of the coding, and the need to review the data to reduce the number of unreadable entries, obtain missing data, etc.

We try to enter data into a computer file as soon as practical after they have been collected. In a trial or survey where there is a single document or field book containing the data, we perform the coding and checking and then enter the data either at the team level, if it is not a great deal of data, or at the central office level where there is a data entry clerk. The data documents and files are kept together so that there is no loss of data. As soon as data are entered in the computer the disk containing the file or files is duplicated, again to avoid loss of data. If the study requires periodic on-going data collection, the data forms are best coded and checked, as received and then entered when sufficient forms have been accumulated. It is important to code and check this type of form to identify potential data collection and coding problems.

Obviously it is desirable to enter data into a database using a computer program that will allow for data transfer to other programs. All of the programs discussed here do permit transfer. Completing part of the anticipated data analysis and discovering that further analysis is to be done in a program which will not take our data as it is entered, is a disaster. No one likes to re-enter data.

10.4.3 CHECKING DATA

Once the data have been entered it is important to make a listing of the data so they can be verified against the original data entry forms. Programs have a "LIST" function which allows the data that have been entered to be printed. In cases where there are a large number of fields it may be helpful to create a ***report format.*** For dBase III Plus this can be done using Quickreport. This will provide a way to organize data, and allow more information on the fields than is usually offered by the "LIST" function. Whether the data are listed with or without a report format, the variables and coding should be easily understood by the user of the data. In a report format, field names can be expanded so that there is no doubt as to the variable's identity. The data should be organized along some pattern so that related variables are together. This will usually be the case when the original data collection form was organized with similar data recorded together.

The final steps in data entry are to check the data in the computer file against the original data, and make any corrections. In addition to direct comparisons done by staff, it is also useful if the researcher does a frequency distribution of those variables (easily done with Abstat) that are not unique to each record. There is of course no point in doing a frequency distribution on farmer identification numbers, as it will list each number just once. The frequency distribution will often identify misplaced or miss-coded entries (i.e., numbers not part of the coding scheme). When the data entry is complete we recommend that the database be documented.

10.5 DOCUMENTING DATABASES

10.5.1 REASONS FOR DOCUMENTATION

When one wants to find a book in a library, one doesn't just start looking through each book one by one. One goes to a catalog or a listing. The catalog is usually organized in

some manner, by subject, author, or title. All of this helps save time when looking for something in particular. Even if one isn't looking for a specific book, one can get a better picture of what is available by looking at the listing.

Any research project, within the government structure, will generate data. We think that this data should be available to anyone else in the government, or outside the government, who has a use for it. Data, whether computerized or not, needs to be organized into a listing or catalog if they are to be used by others. This makes it easier when someone wants to use our data. There are numerous reasons for others to use our data including:

(a). Continue research that we have started.
(b). Comparing our results with theirs.
(c). Using our data to do a different kind of, or a more indepth analysis (i.e., a graduate students working on a thesis).

For a project such as ATIP or other agricultural research projects funded by outside sources, the data generated can be a significant contribution which remains afte. the project terminates, but ***only*** if the data are available to others in a useful form. This means that they must be cataloged, and that each cataloged database must have sufficient information so that a user unfamiliar with the initial data collection can understand the data and their limitations.

10.5.2 FORMAT FOR DOCUMENTATION

ATIP has developed a system for documenting databases. Particulars can be found elsewhere [ATIP, 1988B]. This is a complete system which includes databases and statistical files. If you are organizing your own system, here is some information that should be included:

(a). The title of the data and a description.
(b). The year the data were collected.
(c). The author of the data and the data collection form.
(d). A copy of the data collection form which was used.
(e). Information on the method of data collection.
(f). The location of the data collection forms now, if they still exist.
(g). The type of software used for the data and the data collection forms.
(h). The specific location of the database and the data collection forms, both the disk copies and a print-out.
(i). An explanation of the variables used.

10.5.3 FILE IDENTIFICATION

Finding a particular data file or report which has been entered into a computer can be frustrating if there is no system for identifying files on a computer disk. In order to adequately identify where the data files are located, it is necessary to have some type of numbering convention for the computer disks.[2] In ATIP we have used the convention of a letter followed by three numbers, i.e., A100. The letter identifies the type of material as follows:

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[2]. A computer disk is referred to as a volume, while the individual data sets in a volume are called files.

(a). A = Administration
(b). R = Work plans, annual reports and other reporting documents
(c). D = Databases
(d). W = Working papers
(e). M = Miscellaneous papers
(f). P = Progress reports
(g). S = Statistical files (including Lotus 123 files)
(h). F = Documentation forms (including data collection forms, variable definition lists and status report forms).

The first digit indicates the location of the disk (i.e., 1 = Sebele, 2 = Mahalapye, and 3 = Francistown). The last two digits are the number of the disk within that series, from 1 to 99.

When we prepare a document we include a footer which contains the disk number, file name, page number and the date. This makes it easier to find the original computer document if we wish to. An example of this footer is:

File: M302/MP89.3 - 1 - Date: March 29, 1990

10.5.4 PHYSICAL DATA FILES

We continually face the question of what to do with the physical records pertaining to a particular trial or survey. Physical records include data collection forms (i.e., field books, survey forms, etc.), instructions to enumerators, variable definition forms, coding sheets, results from statistical analysis, and materials used in preparing reports, as well as the reports themselves. While it may not be critical to retain all of these physical records, it is important to keep some of them permanently, specifically the items identified in the database documentation. Other items, such as the data collection forms should be kept as long as there is a reasonable expectation that someone may need to refer to them to cross-check a data item. Generally, we try to keep all of the physical items related to a particular trial, survey or study in a common location. In a major survey, the data collection forms will probably be stored in boxes, and not in the filing cabinets where other documents are stored.

It is desirable to have database documentation on a particular database stored in more than one location. This material is best stored at the team headquarters and in a central data depository. In addition to offering wider availability of the data, storage in two places offers protection from chance destruction.

10.6 TRANSFERRING DATA BETWEEN SOFTWARE PACKAGES

When working with data, doing analysis, and writing the results, ATIP uses five or six major software packages. Table 10.1 provides information on the packages we normally use.

At times more sophisticated statistical packages may be needed by farming systems researchers, or they may wish to create complicated graphics. When the packages described in Table 10.1 are inadequate for a particular situation, the researchers may obtain help and additional computer packages from the biometric staff at DAR.

Some information on using many of these packages is included in other sections of this manual. Specific information is available from the reference material provided with each

program, from the DAR biometric staff, and from other researchers who may be familiar with the individual programs.

TABLE 10.1: SOME CHARACTERISTICS OF COMMON SOFTWARE PACKAGES

PACKAGE	PRIMARY USE	SECONDARY USE	EASY TRANSFER WITH
dBase III Plus	Database entry, editing and storage	Sorting, data manipulation through programming	To: Lotus 123, Abstat
Quickreport	Create listings and other reports for dBase III Plus		From: dBase III Plus
Lotus 123	Spread sheet, simple statistics, tables for Wordperfect	Graphics, direct transfer to Wordperfect	From: dBase III Plus, Abstat To: Wordperfect. Abstat
Abstat	Statistical package for data analysis	Graphics, transfer to Wordperfect using Grab routine	From: dBase III Plus, Lotus 123 To: Lotus 123
MSTAT	Agronomy analysis	Economic analysis	From: dBase III Plus, Lotus 123
Wordperfect	Word processing		From: Lotus 123 (tables and graphics), Abstat (graphics)
Formtool	Designing forms		
Quicken	Financial records program for maintaining votes		
Diskmanager	Cataloging contents of disks		

10.7 USEFUL REFERENCES

Section 10.4:

Caldwell and Walecka, 1987: pp. 294-295.
Shaner, Philipp and Schmehl, 1987: pp. 316-318.

CHAPTER 11: DATA ANALYSIS

11.1 FRAMEWORK FOR ANALYSIS[1]

11.1.1 ANALYSIS IN FARMING SYSTEMS RESEARCH

Analysis of trials is the process by which team members evaluate and interpret trial results to determine the acceptability of a technology to farmers. Through the use of biological (technical), economic, and social/cultural analysis, trial results are systematically examined and are used to predict whether farmers will find the technology acceptable. In the long-run only farmers, not plants or animals, adapt and adopt new technologies. Thus FSR workers must learn to plan, view and evaluate their work from the farmers' perspective -- to see the world through the farmer's eyes.

Analysis and interpretation takes place after a trial is completed, but the planning for analysis must occur before the trial is implemented if maximum use is to be made of information obtained in the trial. The type of analysis planned is determined by the type of trial, but the implementation of the trial is also dependent on the type of analysis to be conducted.

The objective of analysis is to provide information for an integrated interpretation of trials which can be used in planning further farming systems research, identifying relevant on-station research, and/or formulating recommended technologies for extension.

Analysis in farming systems research is performed on the data which are the results generated by on-farm trials, surveys and studies. Once the data are collected and organized the team can apply tools from different disciplines to generate a set of disciplinary analyses which can be considered together in an interdisciplinary framework for final analysis and interpretation.

This chapter discusses many of the disciplinary analysis tools that have been used in Botswana.

11.1.2 TYPES OF ANALYSIS

As a starting point for analysis, FSR workers seek to understand the household and farming environment. An understanding of the household and farming situation is important as it serves as a basis for judging whether a technical change represents an improvement. That is, FSR workers wish to know if a new technology produces more from a given set of resources, meets farmers' requirements with less resources, or helps stabilize inputs and outputs. They also want to know whether the experimental results represent a real improvement for farmers.

Biological (technical) analysis of trials is usually the first step in analyzing the actual trial data. At this step the team determines if the new technology represents a significant biological improvement over the traditional system. The team must decide whether the results were obtained in a "typical" environmental setting, and so are generally applicable, or

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[1]. The material in this section is based primarily on Shaner et al., [1982], and Caldwell and Waleeka [1987].

whether they were produced under "extreme" conditions and must be interpreted with caution.

Once the biological feasibility has been assessed, the data can be subjected to economic analysis to decide whether the farmers will be interested, and have the resources and capabilities to implement the new technology. This analysis can look at profit, risk and other factors such as whether the farmer has or can acquire sufficient capital to implement the technology. Although biological interpretation may be made on the basis of a statistical test using a 0.01 or 0.05 significance level, the economic analysis should also consider technologies that do not meet this level of biological significance. There are two reasons for this:

(a). Farmers may be willing to use a new technology even when research results are not statistically significant. This is particularly true when the farmer's investment is small and the potential results are relatively large.

(b). Even though the level of biological return (yield) may not be significantly greater for a new technology there may be other benefits, such as reduced labor demand at certain times, which make the technology attractive to farmers.

Socio/cultural analysis looks at the technology in a whole farm context and analyses acceptability for the various members of the household who are involved with the technology, determines if there are cultural factors which influence acceptability, examines consumption/nutrition implications, etc.

All of these analyses should include and be tempered by farmers' reactions to the trial and researcher observations. The greater the degree of farmer management in a trial the less quantitative scientific analysis is likely to be possible and the more qualitative farmer and research analysis will be involved. There is a continuum starting with RMRI trials, which have a large amount of quantitative data for scientific analysis, and ending with an adoption study to determine farmer acceptance after the farmers have had a chance to adopt the technology on their own.

Most project oriented farming systems research does not explicitly make an analysis of the environmental impacts of a technology. Researchers may do this subjectively, but it is important to do it explicitly. The whole area of long term impacts of a technology on the environment is of interest to society, and also possibly to the individual farmer. For example, the effect of a cropping system on the long-term fertility of the farmer's land, its impact in increasing or decreasing soil erosion, etc., are areas that deserve more consideration than they are usually given.

The final step is to bring all of the individual analyses together into an integrated interpretation of the trial results. The integrated interpretation of trial results should probably involve farmers and farm family members, researchers, extension staff, on-station researchers, and policy makers. While it may not be possible to get all together in one group to discuss the interpretation of results, all have an interest in this interpretation and should be included at some point. Because different participants have a different view of the benefits and costs from adopting a technology, there may not be a single all inclusive interpretation of the results. An attempt to make an integrated interpretation, however limited, is of value to the farming systems team in designing its future work plans, as well as giving the team members guidance in the question of likely adoption of the technology.

11.1.3 CHOICE OF ANALYTICAL TOOLS

There are numerous tools which can be used in the biological, economic, and social analysis of trial results. The choice of tools depends on the purpose of the trial, the type of trial (RMRI, RMFI or FMFI), the data which have been collected, and the level of training of the researcher carrying out the analysis. While there are many sophisticated analysis procedures available to the researcher, they often have limitations concerning data or implementation of the procedure which cannot be met under farming systems research conditions, so the procedures are inapplicable. We have chosen to use less complicated procedures which are more adapted to field conditions, and which provide the basic information needed for interpreting trial results.

Table 11.1 provides a listing of the primary tools which we have used in biological, economic and social analysis. Most of these tools are discussed in more detail in this chapter.

TABLE 11.1: TOOLS CURRENTLY USED IN FARMING SYSTEMS ANALYSIS IN BOTSWANA

CATEGORY OF ANALYSIS	MEASURE OR INTERPRETATION OF	PRIMARY TOOLS	
		QUANTITATIVE	QUALITATIVE
Biological	Effects of treatments, locations, years, and interactions	Descriptive[a] and t-tests Analysis of variance Least significant differences Correlations and regression Modified stability analysis	Farmer evaluation and observation Researcher evaluation and observation
Economic	Assessment of profitability (costs and benefits), and risk	Descriptive[a] and t-tests Cross tabulation and chi-square Returns to factors of production Budgets -- partial and enterprise Sensitivity analysis Risk analysis Marginal analysis	Farmer evaluation and observations Researcher evaluation and observations
Environmental	Long-term impacts		Researcher evaluation
Social	Inter-household and intra-household equity effects, and consumption/nutrition effects,	Index of acceptability, Modified partial budget analysis Net nutritional benefit analysis Food system calendar	Farmer evaluation and observations Researcher evaluation and observations
General Acceptability	Adoption study	Index of acceptability	Researcher evaluation and observations

a. Descriptive statistics are common to several types of analysis for use in summarizing and describing data. The tools include: frequency distributions, measures of central tendency (mean, median & mode), measures of dispersion (standard deviation, variance, range, coefficient of variation), and graphics (histograms, bar charts, pie charts).

11.2 STATISTICAL ANALYSIS

11.2.1 T-TESTS AND MEANS

11.2.1.1 Purpose Of T-tests And Sample Means

The t-test is a statistical procedure for testing hypotheses about means from single samples of continuous data and about the difference between means from two samples. The t-test is most appropriate for tests on small samples -- sample size less than 30.

11.2.1.2 Description Of T-Tests And Sample Means

When testing hypotheses about the mean from one sample[2], the researcher must have a proposed or hypothetical mean. The difference between the hypothetical mean and the sample mean is evaluated against the standard error of the sample mean (see Section 11.2.3.3(e)) [Snedecor and Cochran, 1967: pp. 59-61]. Suppose a survey was conducted to estimate income in 18 participating farming households. Is the average income in this sample the same as the national average? The national average is part of the researcher's hypothesis proposed before collecting the sample data. The t-test is a test of the difference between the sample mean and test mean using the standard error obtained from the sample.

If two samples have been collected, the test hypothesis can be that they are the same, i.e., have the same mean. For example, if income were measured in seven households in one village and seven households in a second, the test can be whether the two samples from different villages are the same. The t-test uses the standard error of the difference of the mean between the two samples [Snedecor and Cochran, 1967: pp. 93-94].

In the two village example, households cannot be matched; the two samples are independent. If the observations of one sample are paired with observations of the second sample, the t-test becomes much stronger. Take, for example, the comparison of a sample on pH in the 0-20 centimeter soil horizon with pH in the 20-40 centimeter horizon. Paired samples are obtained by taking a top soil and sub-soil sample from each augered hole. Pairing is on the basis of hole.

When pairing, researchers must avoid collecting all pairs from a single replication of the comparison. The pairs must represent independent situations or replications for the contrast. Suppose a researcher wants to compare grain yield samples from fertilized and non-fertilized soil. If all pairs are collected along the length of two adjacent plots at one trial site, each pair will be nearly the same as the rest. Only one independent replication of the paired plots is sampled[3]. The researcher should look for a range of independent sites where fertilized and non-fertilized plots can be sampled.

T-tests are can be one tailed or two tailed. T-tests that are one tailed test whether one sample mean is larger than the other. Two tailed tests look at whether one sample mean is different (larger or smaller) than the other [Snedecor and Cochran, 1967: pp. 97-100].

T-tests can allow for problems in the data. A pooled error variance estimate can be made even when variances of the two samples are unequal [Snedecor and Cochran, 1967: pp. 102-111, 114-116]. When pairing, the two samples are, by design, of equal size; but independent samples need not be of the same size [Snedecor and Cochran, 1967: pp. 104-106].

11.2.1.3 Advantages And Disadvantages Of T-tests

(a). ***Compared With Analysis Of Variance (ANOVA).*** T-tests are comparable to ANOVA F-tests with only two classes. The t-statistic for the t-test is equivalent to the F-statistic where $F = t^2$.

[2]. See Section 7.3.2 for more about samples.

[3]. See Section 11.2.3.4(f) for problems associated with dependent replications.

The non-paired t-test and ANOVA for a completely randomized design (two treatments), work with two independent samples. When two samples are paired, the t-test is more similar to a Randomized Complete Block Design (RCBD) ANOVA; pairs of the t-test corresponding to blocks of the RCBD.

T-tests are slightly preferred over F-tests for two sample comparisons because the t-test shows both the size of a mean difference and its direction. T-tests can also be easily calculated with a calculator once an estimate of standard error of the samples is available.

(b). ***Compared With Chi-Square Test.*** T-tests are used on continuous measurement data whereas chi-square is used to test hypotheses about frequency data. If, however, frequency data with two classes can be assigned values, then t-tests can also be used for the analysis (treated as two samples) [Snedecor and Cochran, 1967: pp. 243-246]. Suppose men and women of farming households were asked to rate from 1 (light) to 5 (heavy), their workload during the month of October. Chi-square evaluates the frequency of responses for men and women in each of the five workload categories. A paired t-test on the effect of sex on perceived workload can be constructed with the multiplication of number of men responding light by the rating 1 paired with the number of women in this category times 1, and so forth.

T-tests, in this situation, are more likely to detect significant differences than chi-square. Caution is in order because the discrete scale of the data can often cause problems with heterogeneity of variances.

11.2.1.4 Software For T-tests

Abstat: Abstat is an exceedingly easy to use statistical package, with the capability to handle calculations of sample means and t-tests.

MSTAT: MSTAT is the statistical package most used by agronomists for on-farm research analysis of variance (ANOVA). MSTAT is able to do t-tests.

11.2.2 FREQUENCY DISTRIBUTIONS, CROSS TABULATIONS AND CHI-SQUARE STATISTICS

Data, particularly survey and other socio-economic data, can be analyzed using a wide range of statistical procedures. Many of these procedures are complex and require good quality data. The quality of data necessary to support many procedures is difficult to obtain under the conditions in which most farming systems teams must operate. For this reason, simple analysis techniques are often more appropriate for farming systems teams. In addition, limiting analysis to simple procedures such as frequency counts and cross tabulations will widen the audience that will be able to appreciate the results [Kearl, 1976: p. 180].

11.2.2.1 Frequency Distributions

A frequency distribution is a way to describe the data. The frequency distribution in discrete data (i.e., 1 = male, 2 = female) is a listing of how many observations there are for each of the different data categories. For example:

Sex of Head of Household	Frequency
Males	120
Females	94

In continuous data, the data must be divided into a number of ranges, and then the number of observations in each range is given. For example:

Cost of Cattle	Frequency
P 100-200	8
P 201-300	36
P 301-400	25

When dividing data into ranges it is a good idea to start with narrow ranges, which can then be combined into wider ranges as necessary.

Frequency distributions are useful in describing the pattern of distributions of sampled variables, for example, sex of head of household, farm size, etc. The frequency distribution can indicate how the sample is divided amongst categories. A frequency distribution is also a good way of looking for data entry errors, as the occurrence of values which are outside the expected range will generally indicate a data problem. For example, if we code villages 1, 2 and 3 but the frequency distribution indicates that there is one observation for village 4, we know there is a data error.

The frequency distribution can also provide a quick summary of each variable. It is descriptive in nature, and does not have any statistical test directly associated with the distribution, so one cannot make statistical inferences from frequency distributions.

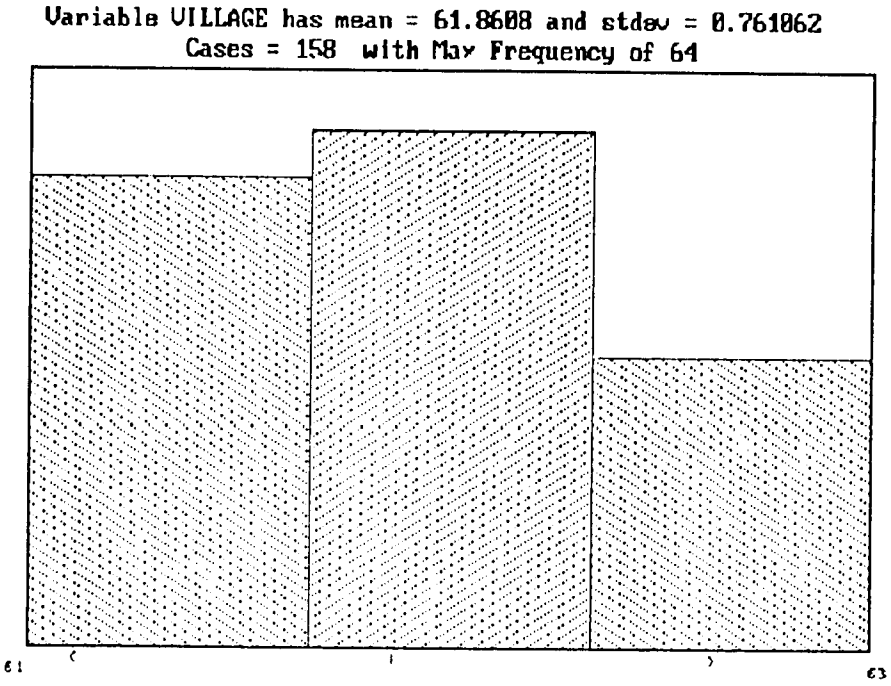
Frequency distributions can be presented in table form, or the data may be presented visually in a histogram. A visual presentation of material is sometimes very helpful in identifying salient features in a data set. A histogram is a bar chart with each bar representing one of the frequency categories with the height of the bar determined by the number (frequency) of observations in that category. The height can either be the absolute frequency or a proportion of the observations in each category. Figure 11.1 is an example of a histogram as produced by the Abstat program. The villages are numbered 61, 62 and 63 (horizontal axis) with the number of farmers in each village indicated on the vertical axis.

Frequency distributions are a basic statistic available in all computer statistical packages. Abstat can produce frequency distributions and the related histograms. It is possible to take a histogram from Abstat and include it in a Wordperfect document, although the Abstat package does not provide the best labels for the histogram.

11.2.2.2 Cross Tabulation

Cross tabulation is a technique for studying the relationship between two variables. It is most often used in examining hypotheses about farmers' behavior. Cross tabulations are usually performed on data collected in surveys. The procedure looks for a relationship by determining if there is some meaningful pattern between two methods of classifying the observations in the data set.

The cross tabulation is related to a frequency distribution in that it involves counting the observations which fall into each cell of a matrix. The matrix is made by assigning one of the variables to the columns and the other variable to the rows. Each column represents one possible response, or range of responses, for that variable, and each row represents the



HISTOGRAM OF VILLAGES, ADOPTION STUDY

FIGURE 11.1: EXAMPLE OF ABSTAT HISTOGRAM

responses for the other variable. Observations are then classified by row and column, and assigned to the appropriate cell, i.e., head of household = 2, village = 1, so there is one observation in cell (2,1). Computer programs provide not only cell counts but totals by row, column and observations. The programs will also provide percentages in each cell for the row, the column, and the total. Table 11.2 is a typical cross tabulation report from Abstat.

TABLE 11.2: TYPICAL CROSS TABULATION REPORT FROM ABSTAT

COMMAND: XTAB

*** CROSS TABULATION ***

Village[a]		New_Tech[b] 1	2	Total
61		13	45	58
	% Tot	8.2%	28.5%	36.7%
	% Row	22.4%	77.6%	100.0%
	% Col	31.7%	38.5%	36.7%
62		11	53	64
	% Tot	7.0%	33.5%	40.5%
	% Row	17.2%	82.8%	100.0%
	% Col	26.8%	45.3%	40.5%
63		17	19	36
	% Tot	10.8%	12.0%	22.8%
	% Row	47.2%	52.8%	100.0%
	% Col	41.5%	16.2%	22.8%
Total		41	117	158
	% Row	25.9%	74.1%	100.0%

Chi Square = 11.4123 Df = 2 Prob = 0.0033

a. Village 61 = Matobo, 62 = Mathangwane, 63 = Marapong
b. New_Tech 1 = Adopted, 2 = Not Adopted

The cross tabulation table provides information about the interaction of the two variables. In this case it tells us that the 13 adopters in village 61 represent 8.2 percent of all the farmers surveyed. In addition, these 13 adopters were 22.4 percent of all farmers interviewed in the village, and were 31.7 percent of all adopters interviewed. By examining the data we can gain some understanding of the differences in adoption by villages.

Cross tabulations can be used to examine hypotheses about farmers' behavior. The hypotheses to be examined can be developed during the exploratory survey, or may be based on other information available to the researchers. In this particular case we originally chose to work in village 63 because it was a "progressive" village. Thus we hypothesized that village 63 would have more adopters than the other more traditional villages. An examination of the cross tabulation supports this hypothesis. The evidence is in column 1, where the column percentage for village 63 is ten percent higher than the next highest village. Additional evidence is provided by comparing the percent of row adopters in village 63 with the percent of row adopters in the total (last row). For all respondents, the percent of adopters is 25.9, while the percent of adopters in village 63 is almost twice that at 47.2 percent.

Obviously the number of cross tabulations that can be performed for a set of date is quite large. We have found that performing all or even half of the possible cross tabulations in a set of data with 25 or so variables will generate so many cross tabulations that it is difficult to interpret them. The important point is to perform cross tabulations which reflect hypotheses we have developed about certain relationships in the data. In practice we have chosen a number of variables that reflect farmers' resources, and which may influence their

decision making. These variables can help to distinguish recommendation domains and include: village, sex of head of household, age of head of household, number of cattle, type of draft, and control of draft. We use these six variables in making cross tabulations with farmer responses in order to attempt to identify differences in recommendation domains for particular activities.

As with frequency distributions, cross tabulation information is relatively easy to report and, particularly when reported in percentage form, can be readily understood by most audiences.

11.2.2.3 Chi-Square Statistic

Cross tabulations provide one way of studying relationships between variables. If the relationship between two variables reflected in a cross tabulation is stated in the form of a hypothesis, the Chi-square goodness of fit statistical test may be used to test whether the hypothesis should be rejected or maintained. While the Chi-square test may be used in a number of different contexts, we use it most frequently in testing for an association between two methods of classification (i.e., two variables).

If A and B are two methods of classifying an observation (i.e., village = 61, 62, 63; and new_tech = 1,2); then the hypothesis to be tested is:

H_O: The null-hypothesis is that there is no association between methods A and B (i.e., between village and new_tech).

H_A: The alternative hypothesis is that there is an association between methods A and B.

For the Chi-square test to be valid, it is assumed that the sample of "n" observations (cases) is random. That is, each observation has the same probability as every other observation of being classified in any cell formed by the intersection of any row and column, independent of other observations.

A detailed discussion of the calculation of the Chi-square statistic and its limitations can be found in most elementary statistical texts -- for example, see Steel and Torrie [1980].

In order to analyze the relationship reported in Table 11.2 we must formulate a set of hypotheses:

H_O: What village a farmer comes from is independent of his/her adopting a new technology.

H_A: An association exists between a farmer's village and his/her adopting a new technology.

The Chi-square test statistic is 11.4123 with two degrees of freedom. Abstat indicates that the probability of this test statistic happening by chance is 0.0033. Thus we can conclude with a 99 percent certainty (P = 0.01) that there is a statistical association between a farmer's village and his/her likelihood of adopting.

It must be remembered that the Chi-square goodness of fit test only works well with a large sample, and requires a minimum of five observations in each cell. Often when we have a small sample of observations, and a large number of categories for each variable, we do not have five observations per cell. If there are several categories in each variable, they may be combined to make a smaller number of categories, and thus increase the possibility of having at least five observations per cell. For example, if we have cattle categories of 0, 1-

15, 16-35, and >35, it may be possible to combine the four categories into two categories, 0-15 and >15.

If the Chi-square test indicates that an association exists between two variables, it is worth looking at the cross tabulations to identify the most probable form of the relationship. In this case we can conclude that for all farmers interviewed, those from the more "progressive" village of Marapong (i.e., village 63) are most likely to adopt new technologies.

11.2.3 ANALYSIS OF VARIANCE

11.2.3.1 Purpose Of Analysis Of Variance (ANOVA)

Analysis of variance, referred to as ANOVA, is a statistical procedure used to test whether the differences observed between the means of treatments and interactions in experiments are significant and not due to chance.

ANOVA is only used with data from designed experiments in which the sources of variation are classified into separate effects, for example, phosphate fertilizer applications of 0, 20, and 40 kg P/ha. to improve sorghum grain yield. In this example, applied fertilizer levels are a source of variation for sorghum grain yield in ANOVA. ANOVA requires a minimum of two replications of each classified effect.

ANOVA is not used with unclassified survey data. As an example; the effect of existing P levels in the soil on sorghum grain yield is not analyzed with ANOVA because P levels, as measured in soils, are not classified treatments. Instead, soil sample P levels illustrate a continuous variable effect. Regression or correlation is used for this analysis (see Section 11.2.5).

Several different procedures can be used to construct the ANOVA. Generally, simple procedures can be used for clean data sets and more sophisticated procedures are needed for messy data. Messy data sets are those with missing values, with unequal numbers of observations, or for which the assumptions of ANOVA are not satisfied. The output of the different procedures, simple or sophisticated, is similar. With widespread access to computers and with back stopping by the biometrics unit, even the most messy ANOVA data can be analyzed, but should be avoided if possible.

In FSR, ANOVA is used in the analysis of most agronomic experiments. However, its value is generally less than in on-station trials because the emphasis in FSR is on farmer assessment and researcher evaluation of non-treatment factors in addition to the ANOVA.

Another fact affecting the role of ANOVA in FSR is the order of magnitude for differences between treatments needed when working with farmers. Substantial differences between treatments -- for example, 50 percent to 100 percent improvement in yield, or a similar improvement in labor saving -- are sometimes needed before farmers would quickly appreciate and adopt new technologies. Thus, there is less need to have precise tests that would detect small differences. In these situations, ANOVA simply verifies what is already obvious to researcher and farmer.

Nonetheless, ANOVA continues to be one of the primary tools in evaluating on-farm research experiments.

11.2.3.2 Description Of ANOVA

The ANOVA offers information about treatment elements and design elements of an experiment.

Different types of treatment structures are discussed earlier in the handbook (see Sections 5.2.1 and 5.2.2). Experiments with a single treatment factor [Snedecor and Cochran, 1967: pp. 258-298] are most common in on-farm research. Such experiments contain two or more classes or levels of the one factor or treatment variable (e.g., variety, tillage system). Other treatment structure types are two factor [Snedecor and Cochran, 1967: pp. 299-338], nested factors [Milliken and Johnson, 1984: pp. 87-91], two or more factors with split-plots [Snedecor and Cochran, 1967: pp. 369-375; Milliken and Johnson, pp. 69-79] and experiments with two or more factors in combination to test the interaction between factors [Snedecor and Cochran, 1967: pp. 339-380]. When interactions between treatment factors can be tested in the ANOVA, the experiment is a factorial. In some instances, two factors are stripped across each other rather than randomized in sub-plots. ANOVA can analyze strip-plots [Gomez and Gomez, 1984: pp. 109-116] but with less strength for the treatment interaction test.

The design structure refers to the manner in which a replication of the treatments is laid out. Nearly all on-farm trials can be analyzed as randomized complete block designs (RCBD) [Snedecor and Cochran, 1967: pp. 299-338; Milliken and Johnson, 1984: pp. 47-54]. Because superimposed trials and "paired comparisons without replication" (see Section 5.2.2.2(a)) usually consist of one complete block of treatments per farm, the ANOVA is handled as a RCBD with farm as the block or replicate. Because farm is the same thing as replication, the interaction of farm by treatment can not be tested. When there are two or more replications per farm -- with replicates in blocks -- the ANOVA is for RCBD with replications nested in location (farms). ANOVA for this design can test the interaction of treatments by farms (see Section 11.2.3.4(g)).

Split-plot designs are often treated as a special treatment structure within a RCBD even though, technically, the assignment of treatments are not completely random within the block. In the split-plot, treatments of two factors, in effect, occupy plots of different sizes. The ANOVA has one level of analysis for the large or main plot factor and another level of analysis for the sub-plot factor.

11.2.3.3 Output Of ANOVA

The steps in an ANOVA are to correctly estimate the error variance, calculate F-statistics, and conduct F-tests that test hypotheses about the treatments of an experiment. The results are presented in an ANOVA table[4].

(a). ***Error Variance.*** ANOVA begins by estimating error variances for treatment means from the data. This is the most important step in ANOVA. There is an error variance for each level of analysis but, because most on-farm experiment ANOVAs have only one level, there is often a single experiment-wide error variance.

(b). ***F-Statistic And F-Test.*** The error variance is then used to calculate F-statistics for the comparison of means in each factor or in each interaction. The F-test compares each F-statistic with predicted F values to test if the F is significant and that

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[4]. Check in any standard statistics text for examples.

therefore, differences between means are significant. Most ANOVA software output includes a probability that the difference means is **not** significant. For example, 0.01 indicates a more significant F-statistic than does a probability of 0.25.

(c). ***Hypothesis Testing Using Multiple Range Tests.*** The standard ANOVA F-test is really testing whether every mean in a comparison is the same. Significant F-statistics signify that some means are different without specifying which ones. It is of greatest importance for researchers to identify which differences are significant.

Multiple range tests are one way of measuring which mean differences are significant[5]. Each multiple range test generates a measurement criterion. If the difference between any two means is larger than this value, that difference is considered significant. The calculation of multiple range test criteria uses the error variance. ***Least Significant Difference (LSD)*** and ***Duncans*** are the most conventional multiple range tests in use, but other tests protect better against making false claims about significant differences [Milliken and Johnson, 1984: pp. 29-45]. Generally speaking, use LSD or Duncans tests only if the comparison-wide F-test is significant (LSD is then known as a Fisher-LSD). And, most importantly, only claim statistical proof of a significant difference if sound technical, economic or other reasons justify making the comparison in the first place. Note that when snooping in data sets with enough comparisons, a researcher is likely to find significant differences even when there are none. The greatest danger of obtaining false claims occurs when comparing a large number of treatments and when some of the treatments have been indiscriminately selected. Fortunately, most on-farm experiments involve small comparisons with treatments that are each carefully selected because of an **a priori** justification.

(d). ***Testing Specific Hypothesis.*** ANOVA is best used in testing specific comparisons or contrasts in the data. Two types of contrasts are tested using ANOVA. First are the partitions of the initial treatment comparison. Compare three tillage-planting systems; early single plow-planting (T1), double plowing (DP), and late single plow-planting (T2). The researcher can ask if T1 yields more than T2. Or, is the average T value (average of T1 and T2) yielding more than DP? The ANOVA is on the sub-set of data that just includes the plots in the contrast. A new error variance and F-test is calculated for this sub-set of data.

A different type of contrast requires restructuring the data to allow new questions, not in the initial ANOVA, to be answered. Take the example of the three tillage-planting systems. To answer the question of whether a farmer profits from DP as opposed to using the plowing to do one part T1 and one part T2, each T1 must be added to T2 in the data set and the contrast then made between the combined value with DP. The researcher may also ask ANOVA to test whether a given profit level is attained by farmers shifting from the use of the combined T1 and T2 to DP. An ANOVA contrast of T1 + T2 + profit is tested against DP.

When ANOVA is used to test hypotheses in the data, the importance of a strong **a priori** justification should not be underestimated.

(e). ***Other Uses For ANOVA Output.*** With this, the ANOVA is complete. However,

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[5]. Many biometricians warn against the overuse and abuse of multiple range testing. Researchers need to be aware of the conditions and limitations for these tests and use them appropriately.

output from ANOVA software can often be used in other ways as well.

i. ***Means.*** Most ANOVA software conveniently prints treatment and interaction means along with the ANOVA table. Only a few older software versions require that means be calculated separately. When the data set is unbalanced, adjusted means are given and should be used by researchers.

ii. ***Standard Error Of The Mean.*** A standard error of a mean in the experiment is calculated using the error variance from the ANOVA [Snedecor and Cochran, 1967: p. 50]. Standard errors describe how much variation is expected between samples from new experiments with the same treatments tested under similar circumstances. Researchers often present standard errors of means when reporting important means from an experiment at a scientific forum. Standard errors are simple and easy to present. When combined with information about the size of the experiment, they contain more information for interested scientific audiences than do LSDs or F-test significance levels. Standard errors of means can also be used to construct confidence intervals and t-statistics.

iii. ***Confidence Intervals.*** Confidence intervals for individual means are constructed using standard error estimates (see Section 7.3.2.6(a)) [Snedecor and Cochran, 1967: pp. 56-57] often produced in ANOVA. Confidence intervals are usually under utilized by on-farm researchers. They are suitable for the presentation of findings to farmers, extension staff and other less research oriented audiences.

Take the example of an economic partial budget analysis of double plow-planting versus single plow-planting. ANOVA is used to analyze the shift to double plow-planting where the partial budget (i.e., profit or loss) was measured on each farm in an experiment. The mean result of + P80.45/hectare in favor of the shift is significant at a 0.001 level of probability. Using a 95 percent confidence interval, profit from the shift to double plowing is P80.45/hectare ± P43.20/hectare.

iv. ***Coefficient Of Variation.*** The error variance of an experiment is used to calculate the coefficient of variation (CV) [Snedecor and Cochran, 1967: pp. 62-64]. The CV indicates the amount of variation for a variable expressed as a percentage of the variable mean.

When related to the output of ANOVA, CVs are mostly used to evaluate the precision of the experiment generating the data. With a high CV, only large differences between means will test significant. CVs of less than 20 percent are considered necessary in most station-based research. In on-farm research, less importance is placed on obtaining low CVs. With farmer management of trials, higher CVs can be expected; particularly for experiments with only a single replication per farm. In order to correctly assess the robustness of technology, it is useful to have the CV in the single rep/farm situation match the CV commonly found between farms. In this way, the researcher knows that the range of experimental environments compares favorably with the target range of environments for the technology.

CVs are also used as descriptive statistics showing the relative amount of variation for a mean. Examples could include:

-- Monthly rainfall totals, January rainfall at Mahalapye is 89 mm. with a CV of 75 percent.

-- Total farm sorghum production, sorghum production per farm in Central Agricultural Region was 254 kg/farm in 1987 with a CV of 120 percent.

11.2.3.4 ANOVA And Special Situations

Even when working with a biometrician, the chances of a useful ANOVA will improve if the on-farm researcher understands some of the situations and problems encountered in research data. Eight data situations that pertain to ANOVA are discussed.

(a). ***Missing Data.*** When data are missing, researchers need to check the cause and handle as appropriate.

i. If there has been inappropriate implementation of a treatment, treat these observations as missing data.
ii. If non-treatment related factors cause plot failure, treat the observation as missing data.
iii. If there is failure of a treatment, treat the observation as a failed response. This means that the zero or low value is used in the ANOVA.
iv. If a single treatment fails while other treatments give some results in a replication, include replication in the ANOVA.
v. With total failure of all treatments for an entire replication or entire farm, do not include replication or farm in the ANOVA.

(b). ***Gross Deviations In The Data.*** When gross deviations are observed in the data, researchers should check the cause. Extreme observations can be tested [Snedecor and Cochran, 1967: pp. 321-323]. The procedure gives the likelihood that the outlier is a mistake and could be thrown out of a data set before the ANOVA. For most questionable data points, a little research can reveal the problem making the outlier test unnecessary.

i. If the datum is incorrectly recorded, correct if possible. If the mistake can not be corrected indicate the data point as missing.

ii. If the datum is an honest result (even though extreme) for that treatment, include it in the analysis.

iii. If the extreme datum is caused by factors other than the treatment (a plot may have crop failure because of a bad patch of soil), the first choice is to still include the point in the ANOVA. Because of the bad data point, the analysis becomes less accurate and less precise. If the trial is small and the researchers are very confident that the extreme result is due to non-treatment factors and not treatment failure, they should check the analysis again with the failed plot datum missing. Most importantly, if possible design plot layouts to avoid areas causing extreme results.

(c). ***Assumption Of Randomness.*** ANOVA assumes that treatments are randomly assigned to plots within each randomized block of the design. Bias will take place if

one treatment is regularly located in a more favorable location than another.

In on-farm experiments, trade-offs are sometimes required that are not usually necessary in station-based work. In tillage work implemented by farmers, a common trade-off dilemma arises when a particular treatment arrangement facilitates implementation but violates the assumption that treatments are randomly assigned to plots. This is justified if the researcher can determine there is no bias caused by the pattern and if, in fact, the treatments are better implemented because of the fixed assignments.

A comparison of T1, DP and T2 is more easily implemented with fewer plowing pattern disturbances if the first plowing is a double plot for T1 and first plowing of DP, and the second plowing is again a double plot with the second plowing of DP in an overlap position on the first plowing and T2 along side. In this way, the plot assignments of the treatments are fixed. The plowing pattern in every treatment is much smoother and uniform, and there is no reason to believe that one treatment is thus favored over another.

(d). ***Assumption Of Normal Distribution.*** The assumption for ANOVA is that if enough sample data are collected, these data would be normally distributed around their mean. This assumption seldom holds perfectly, though generally not too badly. ANOVA is robust with respect to non-normality [Milliken and Johnson, 1984: p. 17]. Even though non-normality can cause ANOVA to produce more significant differences than it should, studies [Milliken and Johnson, 1984: p. 17] have shown that usually the same test result is achieved in ANOVA with non-normal data as with transformed data. With a large number of zero values, it is best to eliminate data from trial sites or replications with complete failure.

(e). ***Assumption Of Equal Error Variances.*** If some treatment means have a larger error variance than others in the ANOVA, too many significant F-tests can result. This problem is a little more serious than non-normality of the data, but ANOVA usually gives good results even with heterogeneous errors [Milliken and Johnson, 1984: p. 17]. See [Milliken and Johnson, 1984: pp. 18-22; Snedecor and Cochran, 1967: pp. 296-298] for information on how to test for homogeneity of error variances.

Analytical methods to handle this problem include variance stabilizing transformations of the data before the ANOVA. These transformations change the data to a new scale which can make interpretation following the ANOVA more difficult.

i. Logarithmic transformations correct problems with correlation of error variances and means; the variance is larger with large treatment means and smaller with smaller means.

ii. Arcsine transformations are used when problems arise with data expressed as proportions. Usually, small variances are associated with either very high or very low proportion means.

iii. Square root transformations help if zeros are frequent in count data.

If the researcher suspects that results of some treatments are very erratic (high error variance) compared with more stable results for other treatments (low error variance), the homogeneity of variances should be tested or a statistician consulted.

(f). ***Independence Between Replications Of A Treatment.*** It is assumed that the handling

of a treatment is not consistently different from other treatments from one replication to another. The assumption of independent handling of the treatments does not always hold in on-farm research. Too often, one treatment is consistently favored by the implementation of the trial or by the handling of data collection.

If most participating farmers in a tillage-planting trial begin with planting the same treatment, that treatment might be favored because soil moisture tends to be a little better early in the day.

Suppose one researcher of a team measures weed levels on early maturing treatments and another uses a slightly different criterion on late maturing treatments. Differences due to measurement method will appear to be part of the treatment effect.

This problem is particularly worrisome because it cannot be recognized in the data. Researchers who supervise trials and data collection must watch for circumstances that create this problem. To avoid the problem, on-farm researchers need to make more use of randomization in order of trial implementation and data collection, and to make every effort to standardize data collection methods.

(g). ***ANOVA Including Different Environments.*** A special ANOVA is used when a trial is conducted over seasons and different places. Contrary to what is sometimes thought, the purpose of testing in a series of environments is not to test the effect of these environments but to see how well the treatment differences hold up. Interest, therefore, is in the treatment by environment interaction.

The following steps take place in the ANOVA involving environments. F-tests, using the experiment error variance term, are administered for each treatment by environment interaction. If any of these interaction terms is significant, a new F-test is made for the treatment comparison, this time using the significant interaction term as the error term. In this way, two pieces of information are obtained. A significant interaction means that some treatments are more suitable for specific environments. A significant treatment difference in the new F-test means that the best treatments are suitable generally over every environment in the experiment.

Several questions about the environments in the experiment must be answered. If there is more than one farm, are farms equal to replication? If so, then farms cannot be tested as environments. However, if this same trial is repeated over several seasons, then seasons can be tested as environments. With more than one replication per farm, season and farms can each be considered environments. Interaction effects will include treatment by season, treatment by farm, and treatment by season by farm. A particular situation exists when the farms in the experiment change from season to season. Then the farm environments are nested within season. The interaction terms are treatment by season and treatment by farm within season. There can be no treatment by season by farm interaction in this analysis.

A specific and very useful situation in on-farm research involves using ANOVA to test for treatment by recommendation domain interactions. The recommendation domains can be soil type, traction type, and so forth. In this ANOVA, farms are nested in recommendation domain and recommendation domain is treated as an environment. With one replication per farm, interaction effects would include treatment by season, treatment by domain, and treatment by season by domain.

Because researchers are interested in making statements (inferences) about how their

treatments will perform for other farmers in other seasons, it's necessary that environments in the trial be a sample, preferably random, of the target environments.

(h). ***ANOVA And Repeated Measures.*** Another special ANOVA is used for repeated measures on the same plots in a trial. For example, in a perennial forage crop experiment, forage yields are measured in each of four successive seasons. There are three options:

Option 1: Combine yields for four seasons and run ANOVA on the sum or the average.

Option 2: Run ANOVA separately on yields of each season.

Option 3: Run repeated measures ANOVA that tests between forage crops within seasons, combined over seasons and changes over time [Milliken and Johnson, 1984: pp. 80-87; Snedecor and Cochran, 1967: pp. 377-379].

11.2.3.5 Examples Of Computer Program Output For ANOVA

The following examples are derived from using the ANOVA-2 and FACTOR sub-programs of MSTAT.

(a). ***ANOVA-2 Analysis.*** The data used are from a hypothetical Cowpea Variety Trial. ANOVA-2 is used to analyze grain yield results from a trial of 4 cowpea varieties tested on 15 farms (1 replicate per farm). Two of the varieties are early maturing and two are of medium maturity. ANOVA-2 and ANOVA-1 are often used in on-farm data analysis and give output typical of other ANOVA packages. Output includes an ANOVA table (Table 11.3).

F-values and probability estimates are given for each effect: "farm" (the replication effect) and "cowpea variety". The mean square error is the error variance for this analysis. ANOVA-2 tests the assumption that variety treatment effects are similar in all replications (non-additivity test). ANOVA-2 output includes the coefficient of variation for the experiment, means for all levels of Farm and Cowpea Variety.

ANOVA-2 is also used to compare early with medium maturity cowpea varieties as an orthogonal contrast. Early maturing varieties (1 and 4) are given coefficients of +1, and medium maturity varieties (3 and 4) a coefficient of -1. The sum of coefficients must equal zero. A separate F-test indicates the significance of this comparison.

(b). ***FACTOR Analysis.*** FACTOR is used to analyze grain yield results in a tillage by phosphate fertilizer Trial. In the example, single plowing and double plowing are combined with and without phosphate fertilizer to give four treatment combinations. This comparison is repeated on twelve farms (1 replicate per farm). FACTOR gives output typical of other ANOVA packages for factorial experiments. This example is for experimental design number 9 with farm treated as replication in FACTOR. The ANOVA table (Table 11.4) gives the F-test for each treatment effect and interaction and the mean square error term. FACTOR output also includes the coefficient of variation for the experiment and means for each treatment combination (not given in this example). The standard error (s_y) for each mean is given.

TABLE 11.3: ANOVA-2 EXAMPLE

Two-way analysis of variance: over Variable 1
Farm (= replication)
with values from 1 to 15
and over Variable 2
Cowpea Variety (1 = early maturity, 2 = medium maturity, 3 = medium maturity, 4 = early maturity)
with values from 1 to 4

Variable 3: grain yield (kg/ha)

ANALYSIS OF VARIANCE TABLE

	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Total	59	3286508.73			
Variable 1	14	1151956.73	82282.624	2.04	.037
Variable 2	3	440545.93	146848.644	3.64	.020
Error	42	1694006.07	40333.478		
Non-additivity	1	238623.57	238623.571	6.72	.013
Residual	41	1455382.50	35497.134		

Grand Mean = 408.767 Grand Sum = 24526.000 Total Count = 60

Coefficient of Variation = 49.13%

Means for variable 3 for each value of 1

VAR 1	1	2	3	4	5	6	7
MEAN	449.000	491.000	268.750	370.000	286.250	586.750	204.750

VAR 1	8	9	10	11	12	13	14
MEAN	651.000	517.250	233.000	342.500	607.500	422.250	445.750

VAR 1	15
MEAN	255.750

Means for variable 3 for each value of 2

VAR 2	1	2	3	4
MEAN	361.200	341.867	376.333	555.667

SINGLE DF ORTHOGONAL COMPARISONS (CONTRASTS)

FOR CONTRAST # 1
1: 1 2: -1 3: -1 4: 1
Sum Of Squares = 148006.667
Effect = 49.667
Error = 25.927
F value = 3.67
Prob = .062

11.2.3.6 Software For ANOVA

Abstat: Abstat is a very easy to use statistical package but with limited application in ANOVA. Abstat only handles one-way ANOVA with and without missing data. This package is more suited for descriptive statistics, regression, chi-square and cross tabulation than for ANOVA.

MSTAT: MSTAT is the most used statistical package for on-farm research ANOVA. MSTAT handles one-factor (ANOVA-1), two-factor (ANOVA-2), factorial data (FACTOR) up to four treatment factors with numerous environment, split or strip plot, nested and repeated measures options (must be balanced without missing data), and a two way ANOVA with unbalanced data and missing

values (NONORTHO). Planned comparisons can be made (Orthogonal Contrasts). This package is moderately user friendly and can process large data sets.

SPSS: SPSS has a full range of ANOVA features including analysis of messy data. SPSS is not for persons without a solid background in statistics and most on-farm researchers need to work with the biometrics unit at DAR to analyze data that requires SPSS.

TABLE 11.4: FACTOR EXAMPLE

Factorial ANOVA for the factors:
Variable 2 with values from 1 to 12
Farm (= replication)
Variable 5 with values from 1 to 2
Tillage System (1 = single plowing, 2 = double plowing)
Variable 6 with values from 1 to 2
Phosphate Fertilizer (1 = 20 kg.P/ha., 2 = none)
Variable 7
Grain Yield (kg/ha)

8. RCBD, 2 Factor factorial

Note: Mean results show that double is plowing better than single plowing and use of phosphate fertilizer is better than without.

ANALYSIS OF VARIANCE TABLE

Code	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Rep	11	1050064.9	95460.4	5.9	.000
2	A	1	453185.3	453185.3	28.0	.000
4	B	1	338016.3	338016.3	20.9	.000
6	AB	1	18644.1	18644.1	1.2	.291
-7	Error	33	534447.3	16195.4		

Coefficient of Variation = 33.99%

$s_{\bar{y}}$ for means group 1 = 63.63052. Number of observations = 4
$s_{\bar{y}}$ for means group 2 = 25.97705. Number of observations = 24
$s_{\bar{y}}$ for means group 4 = 25.97705. Number of observations = 24
$s_{\bar{y}}$ for means group 6 = 36.73709. Number of observations = 12

11.2.4 STABILITY ANALYSIS

11.2.4.1 Purpose Of Stability Analysis

In on-farm research, stability analysis is used to predict the agricultural performance of a treatment (technology) in different environments. The performance of all treatments fall, or rise, depending on the harshness of the environment. The performance of stable treatments, however, is less susceptible to the effect of environment.
The prediction of stability is achieved through the use of a statistical procedure. Estimates for statistics obtained in this procedure are then used as indicators of stability. In this section, the most common procedure, stability analysis using regression, is presented.

11.2.4.2 Description Of Stability Analysis Tests

Stability analysis needs data from a multi-environment test. The same set of treatments is tested in each environment of the test. Treatments could be varieties, tillage systems, and so on. Because the testing required for this procedure is expensive, having treatments without proven potential in at least one environment is not cost effective. A range of environments is obtained by conducting the test at different locations and seasons within a country or target area. A range of environments can also be created within one site by imposing another performance factor. For example, if several irrigation regimes are implemented at one site, the set of treatments can be tested in each regime. The test needs to cover the entire range of environments envisioned by the researcher as targets for these treatments.

In on-farm research, multi-environment tests are common. The testing of a technology to improve grain yield on a range of farms, in different villages and over several seasons, gives excellent data for stability analysis.

11.2.4.3 Use Of Regression For Stability Analysis

Stability is measured from a simple linear (straight line) regression of the performance for one treatment on the index values of the environments. The environmental index is a value that is supposed to define the standard for performance in each environment. To visualize the analysis, consider a scatter diagram (see Section 11.2.5.3(a)). The indices for environments are put on the horizontal axis and the measure of performance on the vertical axis. The environmental index points are not equally spaced. Two environments might have nearly the same index. The straight line regression shows how much change in performance of the treatment takes place for each change of the environmental index unit.

Performance of crop production treatments is usually measured as grain yield. But, performance could also be other measurements such as crop establishment, plant height, weed levels following tillage treatments, profit, etc.

11.2.4.4 Environmental Index

The regression analysis is easy; obtaining good measures of environmental indices is not. Measurements on rainfall, soil depth, soil pH, are examples of indices that have been used in stability analyses. As an example, stability analysis could show how much the yield of a tillage system changes with each 25 millimeter increase in season rainfall. More often, indices are calculated from the performance of treatments themselves. Suppose, yields for double plow-planting are regressed on yields of single plow-planting in data covering 120 farmer implemented comparisons of these systems. The 120 single plowing yields become 120 environmental indices. The regression can explain how much change in double plowing yield takes place with each 10 kilogram increase in single plowing yield.

In the plowing example, yield of single plowing is a good measure of environment because this system is the standard for our farming areas. In other tests, the standard performance is measured as the average of several or all the treatments. Statistically, this is a problem because Y, the dependent variable, in regression, is part of X, the independent variable. Their values are automatically related. Nonetheless, the average of treatments is sometimes used as a measure of environmental index. Take a test of four cowpea varieties conducted on three farms in each of three villages with the test repeated for three seasons. For each of the 27 environments, we can calculate the index as the average yield of the four varieties. Stability is assessed separately for each variety by regressing variety yield on average yield.

For stability analysis to be of use, the range of environments must be adequate. Even though regression can give a prediction of outcomes for environmental indices beyond those in the data (see Section 11.2.5.3(b)), the prediction is not likely to be accurate for environments that are far outside those of the test. Data drawn only from testing in wet seasons with high yields cannot be used to assess stability over dry and wet seasons. Data for stability analysis needs to include a minimum of one environment from each end of a typical range of the indices.

11.2.4.5 Interpretation Of Results From The Analysis

In stability analysis, three regression statistics are used as indicators of stability: the coefficient of regression ("b") and the standard deviation of this coefficient (s_b), and treatment mean.

Because "b" indicates the slope of the regression, it explains whether the performance of a treatment improves faster, slower, or is the same as the environmental index. If the environmental index is expressed in the same units as treatments (yield), "b" equals 1 when treatment and index increase at the same rate. The s_b indicates how much the researcher can rely on the regression relationship. A high s_b means that the performance of the treatment is erratic in good and poor environments. The mean, combined over environments, indicates the general ability of a treatment to perform well.

The stability or adaptation of treatments (technology) is defined as follows:

(a). With good stability or general adaptation, "b" equals 1, mean performance is high and the s_b are low. Other researchers feel that stability is highest when "b" is less than 1 (i.e., the performance does not change much between poor and high environments), mean performance is high and the s_b are low.

(b). With good specific adaptation, "b" is significantly different from 1 (less for if adapted to poor environments and more for better environments). To be considered good specific adaptation, the performance must be relatively high in the environments for which the treatment is adapted and the s_b low.

(c). Poor adaptation is indicated by low performance means regardless of the regression coefficient ("b") or s_b.

(d). Erratic performance is indicated by a high s_b regardless of performance mean or regression "b". Note that sometimes the performance of a treatment appears erratic because the treatment is interacting with factors not part of the environmental index (i.e., a new sorghum hybrid does poorly in an otherwise good environment because of an adverse reaction to a soil factor).

11.2.4.6 Use Of Stability Analysis To Identify Recommendation Domains

One application of stability analysis in on-farm research is for the purpose of dividing farms into groups or recommendation domains (see Section 2.3). When technology is tested under farm conditions, a number of characteristics of the farm combine to make a unique environment: soil type, farm management, and so forth. In a modified stability analysis [Hildebrand, 1984], a treatment result (i.e., grain yield) is regressed on an environmental index consisting of the mean of several treatments tested in an on-farm trial. Farms on which a treatment does significantly better than the index are classified into one

recommendation domain for the treatment. Farms on which this treatment does worse than the index are classified into another recommendation domain.

This method of sorting farm environments works well if the causes of high or low performance are constant from year to year. Unfortunately, in Botswana, variation in rainfall exerts a large influence on the performance of many treatments. This means that the relative performance of the treatment might place the farm in one recommendation domain in one year but in another domain the next season. Therefore, the use of modified stability analysis would need more years data in Botswana than in many other growing environments.

11.2.4.7 Software For Stability Analysis

Stability analysis can be run with any software that does simple linear regression (see Section 11.2.5.5). However, environmental indices need to be calculated separately and entered as the independent variable into the treatment data set. Researchers can use the sub-program REGR in MSTAT to test the significance of differences between stability indicators of different treatments.

11.2.5 CORRELATION AND REGRESSION

11.2.5.1 Purpose Of Correlation and Regression

Regression analysis is used to define a relationship between two or more variables in a data set. One variable, Y, is said to be a function of the variable X or Xs. Y is the dependent variable and X the independent variable. The analysis is also referred to as the regression of Y on X. If cause and effect is being tested; the test is whether X, or the Xs, cause Y to be as it is.

Correlation analysis is simpler. This procedure estimates the closeness of the relationship between two and only two variables. No cause and effect is assumed in this relationship.

11.2.5.2 Description Of Correlation

Coefficients of correlation (r) express the mutual relationship between two variables. The way in which r is calculated does not indicate dependence of one variable on the other [Snedecor and Cochran, 1967: pp. 172-198].

(a). ***Expression Of Coefficients Of Correlation.*** Correlation coefficients range from -1.0 to +1.0. A negative sign indicates that one variable increases as the other decreases; a positive sign, the two variables increase together. Values of ±1 signify a perfect relationship between the variables. Coefficients are expressed in a standard scale; not the scale or units of the two variables.

(b). ***Caution In The Correlation Analysis.*** Correlation is often used as part of a preliminary search for relationships between variables. In this type of data snooping, the researcher must be careful about interpreting results. Because of a likelihood of some error in tests of significance, a percentage of correlation tests will give false significant results. Therefore, correlations without strong cause and effect justification are best used to seek hypotheses for future research and not to draw firm conclusions. If a cause and effect relationship is hypothesized, a significant correlation analysis is more meaningful.

Researchers must also be cautious about basing decisions on correlation coefficients of smaller magnitude than ±0.50, even if statistically significant. The coefficient of determination for r is the square of r, or R^2 (see Section 11.2.5.3(b)). Thus, when r equals ±0.50, the variation in either variable explained by the relationship is only 25 percent. This is a weak correlation if the researcher had no cause and effect justification for making the analysis. When dealing with marginal coefficients, the researcher runs a risk that another factor is causing most of the significance and that the test correlation is spuriously significant (see Section 11.2.5.3(c)).

When planning to use results of correlation analyses to make inferences or statements, researchers should follow a check list of things to look for that is similar to the one for regression (see Section 11.2.5.3(c)):

i. The cause of the relationship must be described by the researcher.
ii. The correlation must be statistically significant.
iii. The coefficient of determination (R^2) must be large enough to indicate that the relationship is useful in explaining variation.

(c). ***Partial Correlation Coefficients.*** Partial correlation coefficients show the mutual relationship between two variables after the influence of a third variable has been subtracted or held constant. To construct partial correlation coefficients, standard coefficients between all the variables are required. Take the example of the correlation between rainfall occurring before planting and sorghum grain yield. The researcher observes that part of the rainfall variable has a large influence on plant stand, but the main objective of this analysis is to determine how stored moisture from before planting directly affects grain yield. The partial correlation coefficient gives the relationship between rainfall and grain yield with the hypothetical circumstance of plant stand remaining at a constant level. The partial correlation coefficient is presented as $r_{\text{rainfall.grain yield/plant stand}}$. Partial correlation coefficients can be constructed with two or more other variables held constant.

11.2.5.3 Description Of Regression

Regression is used less than would be ideal in on-farm research, particularly for technical analyses. Reasons for this include lack of familiarity with its use, and concern that regression is not appropriate for the types of data collected in on-farm research. Care must be taken, though, because regression used indiscriminately often leads to meaningless results.

(a). ***Steps In Regression Analysis.*** To help understand regression, visualize a scatter diagram with the X variable on the horizontal axis and the Y variable on the vertical axis. Researchers could begin by constructing this scatter diagram with their data before the analysis.

The distribution of data points on the diagram may immediately point to a particular type of relationship between X and Y. A line drawn through average points in the data probably illustrates the regression relationship in a reasonable manner. The objective of regression is to find an equation that approximates such a line.

The shape of lines can be straight (linear) or a wide selection of curves. Because they are most common, the fit of a linear regression line is tested first. Before trying to fit non-linear regression lines [Snedecor and Cochran, 1967: pp. 447-471], researchers are advised to consult the biometrics unit at DAR.

The method of least squares is used in many software programs to compute the linear, and non-linear, regression equations. Output of the analysis includes three parts of the regression equation: coefficient of regression or "b", intercept, and standard deviation of "b".

The coefficient of regression, or slope of the linear regression line, is expressed in units change in Y per unit change in X. The intercept is the value of Y, the dependent variable, when X is at zero. The standard deviation of "b" (s_b) describes the goodness of fit for the regression. Special t-tests are used to test the significance if "b" and of the intercept [Snedecor and Cochran, 1967: pp. 153, 155-157] are different from zero or from "b" and the intercept of another regression.

Good regression equations allow researchers to report cause and effect relationships and to extrapolate results for estimating the outcome in other situations. Take the example of planting date and grain yield, a significant and negative equation for the regression of yield on date can be reported as evidence that early planting is a causal factor for good yields under circumstances similar to those of the sample. In another example, a sample of data is used for the regression of travel distance on time spent fetching fire wood. This result is extrapolated to estimate fetching time for many households where only travel distance, and not time, is measured.

(b). ***Special Regression Analyses.*** There are a number of analyses associated with regression analysis. Five are as follows:

i. ***Time Series.*** If the independent variable represents time or events related to time (i.e., stages of plant growth), the regression gives a trend line which can be used in prediction and forecasting. For example, a regression equation is developed with data from an annual market survey on the pattern of oil purchases in villages. If "b" for the linear equation is significant, a prediction can be made on future oil purchase patterns in the sample area. The standard deviation of "b" can be used to calculate a confidence interval for the prediction [Snedecor and Cochran, 1967: pp. 155-157].

ii. ***Multiple Regression.*** More than one independent variable can be introduced into the regression equation. With two Xs, the scatter diagram can no longer be two dimensional. A person must visualize a three dimensional scatter of the data points; horizontal and vertical as before but with a depth axis for the second independent variable. With three or more Xs, the geometry of the scatter diagram can not be visualized, but the regression equation can be estimated [Snedecor and Cochran, 1967: pp. 381-418].

Often, researchers use multiple regression techniques to compare the effects of different Xs [Gomez and Gomez, 1984: pp. 397-423]. Regression analyses for this purpose generally give much less satisfactory results than if the Xs represent treatments in a designed experiment and ANOVA is used. Stepwise sub-programs in software use repeated multiple regression estimations to produce a subset of the Xs that each contribute significantly to a multiple equation. Other Xs that do not contribute significantly are left out of the final stepwise equation. Multiple regression equations can also test coefficients for non-linear terms such as the interaction of Xs [Gomez and Gomez, 1984: pp. 388-397].

iii. ***Tests Of Significance.*** Even correctly developed regression equations are of little use if the equation is not statistically significant. In addition to t-tests

for individual "b"s, ANOVA (see Section 11.2.3) can be used to test statistical significance for the complete regression equation. Most software output includes an ANOVA table with an F-statistic for regression.

iv. ***Coefficient Of Determination.*** Because statistical significance describes the repeatability of results (i.e., likelihood of obtaining a similar result with a new data sample), a better indication of how well regression explains the relationship is needed. The coefficient of determination (R^2) is for this purpose. R^2 equals the proportion of variation in Y that is explained by the regression equation. For example, if R^2 equals 0.24 for the regression of sorghum grain yield on an equation combining season rainfall, soil depth and plow-planting date; 24 percent of the variation in yield is explained by the X variables; 76 percent is not.

v. ***Analysis Of Covariance.*** Analysis of covariance (ANOCV) is a statistical procedure that uses the regression on a continuous variable (X) to adjust another analysis [Snedecor and Cochran, 1967: pp. 419-446]. In agronomic research, the other analysis is usually an ANOVA with classified treatments. The continuous variable must be independent of the treatments in the ANOVA. In the example of a fertilizer trial, the ANOVA for sorghum grain yield may indicate little significant difference between fertilizer treatments because of a large error variance (see Section 11.2.3). The researcher believes that the effect of treatments has been masked because the sub-soil is patchy with a range of shallow and medium deep soils. Soil depth is measured in each treatment plot and used as a covariate in an analysis of covariance. Analysis of covariance consists first of the standard ANOVA for yield. Second, the ANOVA error for yield in each plot is regressed on the soil depth measurement. Third, the new error variance is obtained by subtracting the effect of regression from the initial error term. The new error variance is smaller, and the ANOVA is more precise. The analysis of covariance is for two purposes: to improve the precision of the ANOVA in detecting differences between treatments (fertilizers), and to test the significance of the covariate effect (soil depth) on yield.

(c). ***Problems In Regression Analysis.*** There are a number of problems with regression analysis. Four specific ones are as follows:

i. ***Discrete Scale In The Dependent Variable.*** A regression equation requires a normal distribution for the values for Y, the dependent variable, at each level of X. Suppose a researcher wishes to determine if variation in ratings for cowpea leaf blight, 0 (none), 1 (intermediate) to 2 (all leaves infected), is caused by rainfall following planting. The regression of rating on rainfall will not work because the Y variable is restricted to a few discrete levels; not a normal distribution. Regression could be used if leaf blight were measured as a count or percentage that was normally distributed.

ii. ***Dummy Variables.*** These specially constructed variables can be tested as Xs. independent variables, in a regression analysis [Gomez and Gomez, 1984: p. 403]. Factors that do not have natural numeric values take dummy variables. In on-farm research, dummy variables can be constructed for varieties, villages, farms, recommendation domains, and so forth.

iii. ***Spurious Relationships.*** A frequent and often undetected problem for regression and correlation analyses is the influence an outside factor has on

the dependent and one, or more, independent variables at the same time. What can happen is that the regression appears to be one way within a group of the outside factor, but tests differently when data are combined from several groups.

Suppose the outside factor is season. Then consider the relationship between average yield per hectare and farm area in production. Households that extend farm production over a large area often fail to complete weeding and their average yield per hectare is lowered. The regression of average yield on area is negative. The relationship is the same whether the season is wet or dry. However, if samples from different seasons are combined, the effect of rainfall for the season becomes a factor without being in the analysis. Rainfall causes average yield and area in production to increase or decrease together from one year to another. For the combined data set, regression will show a positive relationship between yield per hectare and area in production. This result is spurious. The analysis within seasons is correct. Check with biometrics staff at DAR about performing regression analysis within groups. Dummy variables representing the effect of groups are sometimes used to perform this regression analysis.

iv. ***Drawing Inferences.*** Researchers who use regression analyses will want to make statements based on the results. When doing so, this short check list of things to look for can be used:

-- The regression equation must be founded on a cause and effect relationship that can be described by the researcher.

-- The regression must be statistically significant.

-- The coefficient of determination (R^2) must be large enough to indicate that the relationship explains a useful part of the variation in Y.

11.2.5.4 Examples Of Computer Program Output For Correlation And Regression

Examples from MSTAT for correlation and regression analysis are given in this section. Data are from hypothetical cultivation plots. They are for weed growth prior to weeding (estimated by the percent ground cover) and weeding labor (measured as the person-hours required to clean weed).

(a). ***CORR Example.*** CORR sub-program of MSTAT produces output typical of other correlation and regression packages. CORR gives information concurrently for correlation and simple regression. For the regression, weeding labor is the dependent variable predicted by weed level.

Output (see Table 11.5) includes statistics on both variables and the correlation coefficient. For simple regression, CORR assumes that the first variable is the independent variable and gives the intercept, the slope "b", and the standard error of the slope (s_b). The standard error of the estimate is the error term for the simple regression equation (i.e., predicted weeding labor time). A t-test is used to test the significance of the simple regression equation.

(b). ***MULTIREG Example.*** MULTIREG can be used for simple and multiple regression. Output (see Table 11.6) includes statistics about dependent and independent variables.

the coefficient of determination, the intercept, the regression coefficient "b" and standard error of the slope (s_b). Standard partial regression coefficients are standardized regression coefficients (range from -1 to +1). They correspond to partial correlation coefficients. The ANOVA F-test, instead of a t-test, is used in MULTIREG to test the significance of the regression equation.

TABLE 11.5: CORR EXAMPLE

```
Weed Level (percent ground cover)
        Variable 1:        Average = 13.95    Variance = 202.36
Weeding Labor (person-hours per hectare)
        Variable 2:        Average = 140.00   Variance = 11232.00

Number = 10
        Covariance = 1443.33        Correlation = 0.957
Intercept = 40.50           Slope = 7.133
Standard Error of the Slope    = 0.761
Standard Error of the Estimate = 32.473
        Student's t value    = 9.374   Probability = .000
```

TABLE 11.6: MULTIREG EXAMPLE

Weed level
Weeding labor (person-hours per hectare)

	Minimum	Maximum	Sum	Mean	Uncorrected Sum of Squares
1	0.50	45.00	139.50	13.950	3767.25
2	40.00	320.00	1400.00	140.000	297088.00

10 cases read 0 missing cases discarded

Determinant of matrix is = 1

Variable Number	Regression Coefficient	Standard Error	Std. Partial Regr. Coeff.	Std. Error of Partial Coeff.	Student t value	Prob
1	7.1326E+00	7.6093E-01	0.9574E+00	1.0213E-01	9.374	.00

Intercept = 40.50076

Coefficient of determination (R-square) = 0.917
Adjusted R-square = 0.906
Multiple r = 0.957
Standard error of estimate = 32.473

ANALYSIS OF VARIANCE TABLE

	Sum of Squares	df	Mean Square	F	Significance
Regression	92651.976563	1	92651.97656	87.86	.000
Residual	8436.023438	8	1054.50293		
Total	101088.000000	9			

11.2.5.5 Summary

Points to note are as follows:

(a). ***Regression And Correlation.*** Because it is used to define a relationship, regression is most appropriate for tests where a hypothesis of cause and effect can be established. When a hypothesis for cause and effect cannot be stated, regression results must be treated with caution. Correlation is most appropriate for preliminary

assessment of simple relations.

(b). ***Regression And ANOVA.*** Regression analysis is one of the more flexible procedures for computing ANOVA (see Section 11.2.3). The biometrics staff at DAR can provide software and back stopping for use of regression in the ANOVA of designed experiments.

11.2.5.6 Software For Regression And Correlation

Abstat: Abstat is an exceedingly easy to use statistical package which does basic correlation analysis, simple and multiple linear regression. Abstat does not do stepwise analysis or analysis of covariance.

MSTAT: MSTAT is the statistical package most commonly used by agronomists in on-farm research ANOVA. MSTAT can handle correlation analysis, simple and multiple linear regression, stepwise analysis. MSTAT is also able to test significant differences between simple linear regression equations. MSTAT cannot do analysis of covariance.

SPSS: SPSS has a full range of ANOVA features including analysis of messy data. SPSS is not for persons without a solid background in statistics and most on-farm researchers need to work with biometrics staff at DAR to analyze data that requires SPSS.

11.3 ECONOMIC ANALYSIS OF TECHNOLOGICAL OPTIONS

11.3.1 OVERVIEW

Economic analysis involves evaluating the "productivity" of different technologies from the point of view of the farmer concerned with conserving his/her most scarce resources. This analysis may include biological (yield) or economic returns to labor at critical times, to land, to seed, to cash or to any other resource needed to produce the technology. We have used the methods discussed in this section to compare experimental cropping and livestock management patterns with existing ones, to judge the acceptability of new technologies to farmers. The quantitative evaluation techniques permit documentation of results which are an objective base for comparison over different years and sites. Despite the need to do analysis of different technologies based on economic procedures, we do strongly agree with Zandstra et al., [1981: p. 62] who conclude:

> " The comparisons, however, are no substitute for farmers' carefully recorded comments about experimental patterns. Researchers should develop, through frequent interaction with farmers, a clear understanding of the attractive and unattractive aspects of the cropping patterns they test."

There are numerous productivity criteria which can be used in socio-economic analysis. One of the traditional criteria is return to land. In many parts of Botswana, land is not a constraint. The critical factor may be availability of draft when there is a planting opportunity, or it may be availability of labor during certain bottleneck periods, such as planting, weeding or harvesting. For many families, who do not market crops or livestock, the most important objective may be to increase food production per unit of labor invested rather than increasing monetary returns over variable costs. We have used returns per hectare (i.e., return to land) in performing partial budget analysis, but have also used returns

to labor or to plowing labor as criteria. While returns per hectare may not be of primary interest to the farmer, they are readily understood by most researchers and allow for interpretation of research results in the light of results reported in the literature. Therefore, we continue to report these results.

While there are numerous techniques for economic analysis, including budgeting, marginal analysis, simulation modeling, optimization techniques such as linear programing, and various methods of risk analysis, we have chosen to use a few straight forward and relatively simple techniques for our analysis of different technologies. We have done this because the relatively simple techniques are most readily understood by planners and non-economists, and because we think that field data are often not sufficiently accurate to support complex analytical techniques. This latter reason is particularly true where the price for most of the inputs and commodities is not determined in a market.

The majority of our economic analysis has fallen into the following four categories:

(a). ***Average Returns Analysis.*** This analysis is the basis for most of the other analyses, and consists of a listing of the average costs of producing a particular product and the average value of the product for each technology being compared. The cost-and-returns analysis requires information on both variable and fixed inputs. We have often used a more limited average variable cost-and-returns analysis to compare different technologies which use the same fixed inputs. This information can be used to compare the average returns above variable costs (RAVC) for different technologies and the returns to other production factors such as total labor or plowing labor. The process of valuing inputs and commodities is of particular importance in making realistic cost-and-return analyses, and will be discussed in its own sub-section.

(b). ***Budget Analysis.*** There are several types of budget analysis. The ***enterprise budget*** is a statement of costs-and-returns (both variable and fixed) for a particular enterprise (or technology). This type of budget can be used as a building block in making ***whole farm budgets***, and in estimating the impact of a change to the new technology. The ***partial budget***, on the other hand, is a direct comparison of the elements within enterprise budgets which change between technologies. This type of budget requires less data than the enterprise budget and offers the advantage of direct comparison. Finally, whole farm budgets can be used to look at allocation of resources between enterprises, and at the impact of a new technology on the allocation of resources to other enterprises on a farm. We have most frequently used the partial budget technique for comparing different technologies which have been undergoing biological testing.

(c). ***Marginal Analysis.*** Average returns and budget analysis are based on average data values acquired from a number of replications of a trial, all of which use the same level of variable inputs. Thus we are making comparisons between technologies based on a given level of inputs. Marginal analysis allows us to go beyond the comparison of a given level of inputs and look at profitability as levels of variable inputs change. This addition allows us to make some determinations as to the best (most efficient and profitable) allocation of resources for a given enterprise. Unfortunately marginal analysis requires data over a wide range of inputs, something that has not been available in much of the farming systems work in Botswana, so marginal analysis techniques, while valuable, have not been widely used.

(d). ***Risk Analysis.*** When a farmer undertakes a crop or livestock enterprise she/he always faces the risk of failure and loss of their time, cash or other inputs invested

in the enterprise. When farmers consider a new technology they are concerned about the risk involved in the new technology compared to the risk of their present technology. Measuring risk is difficult, and is of somewhat limited value as different farmers look at risk differently. Our approach to risk analysis has been kept as simple as possible. Some indications of risk have been obtained from doing ***sensitivity analysis*** with partial budgets. Two additional tools we have used are ***stochastic dominance analysis***, which assumes that farmers prefer more profit to less, and a ***modified safety-first analysis***, which provides information on the likelihood of returns from a technology falling below a minimum acceptable level.

There are a number of steps involved in performing an economic analysis of technology trials. These will vary with the type of trial, the audience who will use the information, the computational equipment and experience of the scientist making the analysis, etc. Some of the basis steps we go through for many trials are:

(a). ***Review Objectives Of The Trial.*** The objectives of the trial will determine what analysis should be included, and what additional analysis we may want to include.

(b). ***Review Experimental Design And Management.*** Some techniques are only valuable with certain types of trials. For example, enterprise analysis is of limited value when trials are performed on un-representatively small plots, since one cannot make conclusions about the level of inputs for the enterprise when it is operated on a large scale.

(c). ***Choose The Analysis To Be Undertaken.*** Based on the objectives and experimental design, and to some extent on the availability of data, choose the set of analysis to be performed.

(d). ***Calculate Average Yields.*** Calculate the average biological outputs for the various technologies under investigation. In some cases, particularly with animal trials, there may be a number of outputs.

(e). ***Identify Inputs And Levels.*** Identify inputs and the quantities of each. In some analysis it is only necessary to identify inputs which vary between technologies being tested.

(f). ***Calculate The Costs And Benefits.*** Appropriate price data will be needed to calculate the costs and benefits. For some types of analysis not all inputs or outputs must be costed.

(g). ***Calculate The Average Returns Above Variable Costs (RAVC).*** If there are data on all variable costs, or if coefficients can be used for missing variables, it is possible to calculate the average returns above variable costs.

(h). ***Do Partial Budget Analysis.*** Create partial budgets comparing the different technologies, including the traditional technology. Determine if there is an advantage to adopting the new technology.

(i). ***Perform Marginal Analysis.*** Calculate marginal rates of return and compare to minimum acceptable rate.

(j). ***Make Risk Assessment.*** Based on sensitivity analysis, stochastic dominance, or minimum return (safety first) analysis, draw some conclusions concerning risk.

Which of these steps can be undertaken will often be dependent on the type of data available. There are many measurement problems in doing farming systems research. At times it is not possible to collect all of the data needed for an economic analysis, or the data collected as suspect. It may be necessary to make estimations of individual data values or to use coefficients for some activities (particularly labor coefficients) in order to perform a particular analysis. With integrated trial design involving all team members, and close supervision of field activities, the need for making estimates and for using coefficients can be reduced. While it may be practical to use coefficients for some labor activities, such as broadcast planting or plowing which are common to all technologies being tested, it is important to collect actual labor data for activities which may be different between trials, such as weeding times where there is an additional tillage operation which may reduce weed burden on one of the trial plots. Obviously, it is desirable to have all measurements as accurate as possible, but given field conditions it may be desirable to settle for less than perfect data. Thus the analysis we perform should be appropriate for the quality of data that are collected.

11.3.2 VALUING INPUTS AND OUTPUTS

One of the major problems in performing an economic analysis is what value to assign to the inputs into a trial and the outputs from the trial. The objective of valuing the inputs and outputs is so that they are represented in a common unit. It is not possible to directly compare hours of labor and kilograms of grain, so if they are to be combined for analysis they must be converted to a common unit. While it is possible to use other units, such as kilojouls of energy, the standard practice is to convert everything to a monetary unit, i.e., the pula. If all inputs were purchased, i.e., seeds, fertilizer, hired labor, rented land and equipment, it would be relatively easy to calculate the value of inputs. In the same way if all outputs were sold, it would be easy to calculate the value of the benefits from the technology. Unfortunately, researchers working with limited resource farmers in Botswana do not normally deal with inputs and outputs that are based on cash transactions.

There are a number of concepts that will help in understanding the valuation of inputs and outputs. These are:

(a). ***Inputs And Outputs.*** An input is any resource (physical good or service) which goes into production of an output. Inputs can be divided into two classes:

i. ***Fixed inputs*** are resources such as land which remain constant for different technologies used for producing a particular crop or animal, i.e., one hectare of land.

ii. ***Variable inputs*** are resources which change between technologies, such as the amount of fertilizer applied or labor used.

Outputs are the product received from a particular farming activity and include grain yields, stover, meat, eggs, manure, etc. Both inputs and outputs can be valued in much the same manner.

(b). ***Price And Cost.*** The price of an input is the value which must be given up to bring an extra unit of the input into the production process. The cost of an input is the price times the number of units used in production. Similarly the price of an output is the value of one unit of the output where as the benefit is the price times the number of units sold.

(c). ***Costs And Benefits.*** Costs are the total value of an input or inputs while benefits are the total value received from the product or products from an activity.

(d). ***Cash Costs (Benefits) And Opportunity Costs (Benefits).*** If a farmer purchases seed from a general dealer to plant, that is a cash cost. The value of the seed for use in analysis is the actual money the farmer paid. Sale of an animal for cash is likewise a cash benefit. Many inputs are not paid for in cash since they are provided by the farmer or are acquired without a direct cash cost. The same is true of benefits, many outputs are used by the farm family directly and not sold. In this case, the input or output can be valued using its opportunity cost. The opportunity cost of an input or output is its value in its best alternative use. Thus the opportunity cost of labor is its value in its best alternative use, i.e., if a person can get a job in town, the value of his/her labor in agriculture is the value of an equal amount of time worked on the job. Likewise the value of an animal product, such as meat, is the amount the family would have to pay to purchase that meat instead of using their own product.

(e). ***Field Cost And Field Benefits.*** The field cost of an input is the cost of the input where acquired plus any costs, such as transportation, required to bring it to the production site. The field benefit is the total value of a product at its sale point minus any transportation, storage, and/or marketing costs in delivering it to the sales point.

(f). ***Field Price.*** The field price of an input or output is the value of one unit of the input or output in the field. Field prices are purchase prices or selling prices adjusted for transportation and marketing. If prices of individual units are hard to obtain it may be easier to calculate field prices from field costs and benefits by dividing the field cost of an input by the number of units of input or the field benefit of an output by the number of units of the output.

(g). ***Private Versus Social Costs And Benefits.*** In valuing inputs and outputs for management studies, inputs/outputs are normally valued at their cost/benefit to the farmer. If the farmer receives an input subsidized by the government, his/her actual cost -- including transportation -- is used as the value. For certain types of studies, i.e., policy studies and project evaluation studies, the actual costs/benefits to society are used. Thus for this type of study the cost to the government of a subsidized item is used as its value.

In valuing an input or an output, FSR workers generally wish to determine a field value. For budgeting and other economic analysis the critical job is determining a realistic field price for all inputs and outputs. One must take the actual resources used or outputs produced and use either actual cash prices or opportunity prices to value these inputs or outputs. Some specific considerations in valuing inputs and outputs are:

(a). ***Valuing Fixed Inputs.*** A fixed input is one which does not change with level of production, e.g., land which the farmer has whether he uses it or not. Fixed inputs include land, buildings (**kraal**), equipment. Land in Botswana is often impossible to value as the farmer does not pay for it nor does he/she pay taxes on the land. It is possible to assign a value to land based on destumping and/or fencing costs. In this case it is necessary to decide how long the land can be used and divide the initial cost by the number of useful years to get an annual land charge. This is a problem when the farmer uses a mixture of old and new land. Equipment is usually valued based on depreciation. A simple formula for depreciation is the original cost minus any expected salvage value divided by the number of years of useful life. This will

give an estimated cost per year. In practice it is very difficult to value most of these fixed assets, so if a value is needed it is often easier to make an estimate rather than trying to calculate the actual costs.

(b). ***Valuing Variable Inputs (Non-Labor).*** A variable input changes with the level of production, e.g. if the farmer does not plant she/he uses no seed, if planting is done, seed is used. Non-labor variable inputs include seed, fertilizer, stock feed, equipment repair, etc. Where these are actually purchased, the cash cost is used. When items are received from the government, the actual cost to the farmer plus transportation, is used. If the farmer provides the input, e.g., seed from the previous year's harvest, an opportunity cost equal to what it would cost to purchase the item, is used.

(c). ***Valuing Labor.*** Because labor is the primary input most farmers make into agriculture, it is important to make a reasonable valuation of labor value. Unfortunately labor is also one of the more difficult items to value. There are several specific problems in valuing labor including:

i. For most farm household members, off-farm employment is not really an option, so it is not possible to use off-farm wages as an opportunity cost.

ii. For many household members, particularly women and children, there are no paying alternatives to on-farm work. In some cases beer brewing could be considered an alternative.

iii. Likewise, old men and young boys working on a cattle post may well not have any alternative wage opportunities. If they are paid in-kind (one beast a year) or a wage, this can be used.

iv. Often work is a joint activity, i.e., child care and bird scaring, so there is a problem not only of valuing the labor but of allocating it between what is often an agricultural and a non-agricultural activity.

It does not matter if we are trying to value labor which has been measured directly or is based on standardized coefficients, the problem of valuing still remains. The only regularly available alternative source of employment for many village members is the Labor Based Drought Relief scheme. Thus we have often used the Labor Based Drought Relief wage as the value for agricultural labor. In the few cases where agricultural labor is hired, the actual wage rate -- including in-kind payments such as food and drink -- can be used.

(d). ***Valuing Outputs.*** If the outputs are sold, i.e., sale of an animal, then the value is easily determined. If an item is consumed, then the appropriate value is what the same item would have cost if purchased. This is not too difficult to determine if there is a local trade in the particular item, i.e., sale of **madila**. However, there are many outputs which are not sold, i.e., stover, manure. How can these be valued? Sometimes a close substitute can be used to value an output. For example, the Livestock Advisory Center (LAC) price for sorghum stover or even hay might be used to value stover -- with proper adjustments for transport costs, etc. Or it would be possible to use the value of the cost of labor to collect the output, again in the case of stover if it is cut and stored for later feeding the value could be the cost of the labor to collect it. See Section 4.2.3.3 for some special considerations in valuing livestock products.

No matter how inputs and outputs are valued, it is important to carefully explain what has

been done when reporting the results so that others can evaluate the criteria for relevance to their situation, and make adjustments accordingly.

11.3.3 AVERAGE RETURNS ANALYSIS

The analysis of the average (mean) costs/benefits from different technologies being examined in a trial is one analysis which is often made. Where all of the relevant data have been collected, this type of analysis can be used. However, this requires valuation of both fixed and variable inputs, and in many cases, the variable inputs are what need to be examined as the fixed inputs are constant for all plots in the trial. Thus the most common analysis performed is an analysis of the average returns above variable costs (RAVC). This allows a comparison between various technologies being tested based on the inputs the farmer must provide.

The procedure for calculating returns above variable costs is:

(a). Calculate an average yield or an average amount of product for each separate technology.

(b). Calculate average inputs (usually emphasizing labor inputs) for each technology separately.

(c). Calculate the gross returns (gross total value product) which is the yield times the appropriate field price for the product, or products if there are more than one.

(d). Calculate the variable costs associated with each technology. The variable costs for a crop trial usually include labor, seed, draft hire (if hired draft is used), and a charge for equipment depreciation.

(e). The average return above variable cost (also called net return) is then calculated by subtracting the variable costs from the gross total value product.

(f). These average net returns can then be compared between technologies. Some scientists believe that the return for a new technology must be at least 30 percent higher than for the traditional technology before farmers will be willing to consider adopting the new technology [Zandstra, 1981: p. 63].

This analysis is generally on a per hectare basis and the return calculated is a return to management, assuming that land is fixed and that labor has been valued at the price of its best alternative use.

In order to maximize profits it is necessary to maximize returns to the most limiting resource. In Botswana land is often not the most limiting resource. The most limiting resource may be traction time or labor for plowing or weeding. When the most limiting resource is known, it is possible to calculate an average return to that resource for the different technologies being compared and choose the most favorable technology. This procedure will not maximize the returns since it does not examine different levels of inputs, but it will maximize the returns to the most limiting factor for a fixed level of inputs. For example, we can calculate a return to weeding labor by omitting weeding labor costs (all other labor costs are included) from the cost total and then dividing the return by the number of hours of weeding labor, giving a return per hour of weeding labor. Table 11.7 shows a returns to labor analysis, for preparation labor, weeding labor, and total labor, involved in growing sorghum

TABLE 11.7: NET RETURNS TO LAND AND LABOR FROM GROWING SORGHUM IN DOUBLE PLOWING TRIALS, FRANCISTOWN, 1985-87[a]

	YIELD (KG/HA)	ACTIVITY TIME (HRS/HA) PREP[b]	WEED[c]	TOTAL	RETURN (P/HA) GROSS[d]	NET[e]	NET RETURN (P/HOUR) PREP	WEED	TOTAL
AV SINGLE PLOW									
1985-86	166	33	32	103	71.29	68.59	1.32	3.08	0.63
1986-87	54	28	36	75	23.26	20.56	0.07	0.55	0.31
2 Year Average	110	31	34[f]	89	47.28	44.58	0.70	1.59	0.47
AV DOUBLE PLOW									
1985-86	347	71	48	185	149.34	143.94	1.85	3.91	0.79
1986-87	109	58	37	124	46.76	41.36	0.21	0.79	0.35
2 Year Average	228	64	43[f]	154	98.05	92.65	1.03	2.17	0.57

a. Most of the data in this table are derived from results presented in Worman [1987], and involve trials for which labor data were recorded. The trials were research managed and farmer implemented (RMFI) with a sample size of 20. Planting of the single and double plowed plots were done on the same day. Figures in the table are the average per plot.

b. Preparation time includes plowing and planting.

c. Consists of weeding time only.

d. Gross return equals yield X price where the price of sorghum is P0.43/kg.

e. Net return equals gross return minus costs where costs equals seed (P0.30/kg for 4kg) plus depreciation on equipment (estimated at P1.50/ha). In this calculation, labor has not been costed.

f. The difference in these figures has been the opposite way round for other ATIP trials undertaken at both Francistown and Mahalapye. From a sample size of 59 paired comparisons, the average weeding time per hectare for single and double plowing was 34 and 19 hours respectively. Such figures make the return per hour of weeding on double plowed plots even more attractive.

11.3.4 BUDGETING

There are several types of budgeting including whole farm budgeting, enterprise (or technology) budgeting and partial budgeting. The enterprise budget provides an estimate of costs and returns for a specific farm enterprise (i.e., production on a specific area using a single technology and a specified production period). The whole farm budget combines enterprise budgets for all enterprises on the farm to provide an overall picture of the farm costs and returns. The partial budget, on the other hand, is a way of analyzing differences in costs and benefits of two or more competing enterprises or technologies. While each type of budgeting has a role in economic analysis, the partial budgeting procedure is probably the most useful in FSR.

11.3.4.1 Approach To Making Budgets

A good start for any economic analysis of a technology is to make a statement of the farmers' objectives, especially as they relate to the particular farm enterprise/technology.

The second step is to make a detailed description of the technology or enterprise. This step includes:

(a). Determine the "unit of analysis". The unit of analysis may be for an enterprise or technology, such as sorghum production using double plowing on one hectare for one crop season, or the meat production from 100 goats for a year. It may also be a combination of enterprises such as sorghum, millet and minor crops on 10 hectares for a year which might be most easily done by doing individual enterprise budgets.

(b). Identification of all operations that will be performed. For crops, this includes land preparation, tillage operations, applications of pesticides, fertilizers, etc., and marketing activities. For animals it will include herding labor, milking or slaughtering, marketing, etc.

(c). Using experimental data where available, estimate the quantities of inputs for each operation, i.e., labor, chemicals, etc.

(d). Determine the "field price" of purchased inputs, equipment, labor, etc. whether it is a cash cost or an opportunity cost. Multiply the price by the number of units to get a total cost for that input (see discussion in Section 11.3.2).

(e). Using experimental data, where available, identify the quantities of all outputs such as grain, fodder, meat, hides, etc.

(f). Determine a "field price" for all outputs, whether sold or used by the household. Multiply the price by the number of units to get a total value for the particular benefit.

Using this type of data the various budgets can be constructed.

11.3.4.2 Enterprise Budgets

The enterprise budget is a projection of costs and returns for a specific farm enterprise, where the farm enterprise uses a single technology and is identified by unit of production and time period of production. For example, one hectare of double plowed sorghum production during one crop season, production from four goats in confinement for a year, etc. The enterprise budget normally includes an estimate of the physical resources (e.g., seed, labor, fertilizer, etc.) required and products produced (e.g., kilograms of sorghum, liters of milk, etc.), their prices, and the total value of each resource and product per unit of the enterprise for the production period [Boehlje and Eidman, 1984: p. 167]. This information is combined in an enterprise budget format to give an average returns above variable costs (RAVC) figure for the enterprise. The RAVC is the "bottom-line" for an enterprise budget.

A typical crop enterprise budget which can be constructed from data collected in an on-farm trial is shown in Table 11.8. Form 11.1 is an outline for collecting data for a livestock enterprise budget.

The enterprise budget is an estimate of costs and returns from producing a unit of a particular crop or livestock enterprise. For the example in Table 11.8, the value placed on the different items is critical in determining if there is a positive net return[6]. In this example, labor was valued at the Labor Based Drought Relief wage. Since the family usually provides most or all of the labor, this may not be an accurate labor cost. The same information used in the enterprise budget can be used for estimating returns to labor, which may be of more interest than returns to hectare as calculated in the enterprise budget[7]. The enterprise budget also serves as a building block for calculating a whole farm budget.

11.3.4.3 Whole Farm Budgets

Where the introduction of new technologies will force farmers to reorganize their farming operation, either over time or all at once, a whole farm analysis needs to be undertaken. A whole farm budget includes a listing of all production and income, and all inputs and

[6]. See Section 11.3.2 for a discussion on valuing inputs and outputs.

[7]. See Section 11.3.3 for a discussion of returns analysis.

expenses for the farm. The whole farm budget consists of a table of resources available for the farm, primarily land and labor (by month), enterprise budgets for the enterprises to be undertaken, and complete budget for a specified time period (usually a year) listing the income and expenses from the combination of enterprises chosen. Often a farmer may choose from several enterprises, which compete for land and/or labor. In this case, several budgets must be prepared indicating different allocations of resources among the enterprises, and the most profitable is chosen. Generally this is a time consuming process and the use of linear programming or other types of farm modeling is recommended. Numerous sources are available for further information on whole farm budgets, use of linear programs, etc[8].

TABLE 11.8: ENTERPRISE BUDGET FOR DOUBLE PLOWED SORGHUM/MILLET PRODUCTION ON ONE HECTARE, FRANCISTOWN AREA, 1985-87

ITEM		UNIT	QUANTITY	PRICE OR COST/UNIT (PULA)	VALUE OR COST (PULA)
1.	Gross receipts (benefits)				
	Sorghum/millet	Kg	228	0.43	98.04
2.	Operating costs (variable costs)				
	Seed	Kg	4	0.30	1.20
	Labor	Hr	154	0.38	58.52
	Total operating costs	Ha			59.72
3.	Income above operating costs (gross margin)				39.52
4.	Ownership costs (fixed costs)				
	Depreciation on equipment	Ha	1	1.50	1.50
	Total ownership costs				1.50
5.	Total costs shown				61.22
6.	Net returns above costs shown				36.82

Source: Adapted from Worman [1987].

11.3.4.4 Partial Budgets

Partial budgets are a useful tool for analyzing small changes in farming systems. This type of change is common in FSR in harsh environments such as Botswana. Partial budgeting requires less information than a whole farm budget or an enterprise budget. It measures changes in income and returns to limited resources, provides a limited assessment of risk, and through sensitivity analysis suggests a range of prices or costs at which a technology becomes profitable [Mutsaers, Fisher, Vogel and Palada 1986: p. 150].

Partial budgeting is a method of organizing experimental data and information about the costs and benefits from some change in the technologies being used on the farm. Partial budgets are not used to estimate the total income and costs for each of the technologies being considered. The goal is to estimate the difference in benefits or losses expected from the technologies.

The partial budget technique is often used to compare a new technology with the existing technology. This is most useful where the new technology consists of the existing technology with one or two changes. The following steps are used in creating a partial budget:

[8]. For example, see Boehlje and Eidman [1984: pp. 229-236, 392-429].

FORM 11.1: SAMPLE LIVESTOCK ENTERPRISE BUDGET FORM

Kind of Enterprise _____

Description of Production (one unit includes) _____

ITEM							TOTAL VALUE
1.	Description of Enterprise Receipts (from one unit):						
	_____						P_____
	_____						_____
	_____						_____
	Value family consumed products P + manure value P						_____
2.	Gross Receipts per Unit						P_____
3.	Cost of Feed (excluding waste):	Amount		Price			
	a. Pasture.....	____	x	____	=	P_____	
	b. Hay, etc.....	____	x	____	=	P_____	
	c. Grain.....	____	x	____	=	P_____	
	d. Concentrates.....	____	x	____	=	P_____	
	e. _____	____	x	____	=	P_____	
4.	Total Feed Variable Costs					P_____	
5.	Other Variable Costs:						
	a. Veterinary and Medicine....	____	x	____	=	P_____	
	b. Feed Preparation.....	____	x	____	=	P_____	
	c. Other:_____	____	x	____	=	P_____	
	d. _____.....	____	x	____	=	P_____	
6.	Total Other Variable Costs					P_____	
7.	Total Variable Costs Per Unit (L.3 + L.6).....						P_____
8.	Gross Margin Per Unit (L.2 - L.7).....						P_____
9.	Investment Required Per Unit						P_____
10.	Labor Required (Hours Per Unit)						_____ (hours)

Source: Caldwell, Taylor and Walecka [1987: pp. 273].

(a). Identify the elements in the production process that are different (such as purchased inputs, different labor requirements, etc.).
(b). Quantify inputs which are different for the technologies.
(c). Calculate a "field value" (quantity used times field price) for each input.
(d). Outputs where there are differences are also identified, quantified and valued.
(e). Organize this information as outlined in Table 11.9, resulting in a presentation of information such as is given in Table 11.10.

To interpret this partial budget (Table 11.10), note that the increase in benefits more than makes up for the reductions in benefits. Even though there are more costs associated with the new technology, there is a net gain of almost P20 per hectare from using the new technology (double plowing) over the traditional (single plowing) technology. In its most simple interpretation it does pay to switch from single plowing to double plowing in conditions similar to those where the tests took place. The change (increase) in benefits was larger than the change (increase) in costs necessary to produce that benefit [Caldwell, Taylor and Walecka, 1987: p. 264].

A partial budget is easy to interpret. However, it is rarely presented with a statement of the farmer's objectives, the farmer's resource base, and important non-cash considerations. A

first consideration should be the question: does the criterion of increasing net benefit per hectare imply that it is in the farmer's interest to maximize returns to land? Often, this is not the case. The partial budget does not tell us if the draft and labor are available to the farmer to do a second plowing, or if the farmer has the capital to hire a second plowing, if plowing is done through a hire arrangement. For many farmers the availability of labor or capital may be more constraining than the availability of land. The evaluation criterion used should maximize returns to the most constraining variable [Caldwell, Taylor and Walecka, 1987: p. 265].

TABLE 11.9: PARTIAL BUDGETING FORMAT

1.	**Additional benefits:**	List the items of income from the new technology that will not be received from the existing technology.
2.	**Reduced costs:**	List the items of expense for the existing technology that will be avoided with the new technology.
3.	**Subtotal increases:**	Add lines 1 and 2.
4.	**Reduced benefits:**	List the items of income from the existing technology that will not be received from the new technology.
5.	**Additional costs:**	List the items of expense from the new technology that are not required with the existing technology.
6.	**Subtotal decreases:**	Add lines 4 and 5.
7.	**Difference:**	A positive (negative) difference indicates that the net benefits of the new technology exceed (are less than) the net benefits of the existing technology by the amount shown.

Source: Based on Boehlje and Eidman [1984: p. 237].

While a partial budget gives an indication of which of two or more technologies is "better", it does not answer the question of what is "the best". There are two problems that partial budgets do not directly address:

(a). The partial budget may indicate that the new technology is "better" than the traditional technology, but it will not show that both technologies produce a loss. An enterprise budget would show this type of information.

TABLE 11.10: PARTIAL BUDGET: DOUBLE PLOWING INSTEAD OF SINGLE PLOWING A SINGLE HECTARE, MAHALAPYE AND FRANCISTOWN AREAS, 1983-87

ITEM	PULA	PULA
REDUCED COST (in Pula)		
Weeding Time Saving (6.2 hrs @ P0.38/hr)	2.36	
Single Plow Harvesting Time (25 hrs @ P0.38/hr)	9.50	
ADDED BENEFITS		
Double Plow Yield (197 kgs @ P0.43/kg)	84.71	
SUB TOTAL INCREASES		96.57
ADDED COST		
Double Plow Second Plowing (29.7 hrs @ P0.38/hr)	11.29	
Depreciation on Equipment	1.50	
Double Plow Harvesting Time (43.8 hrs @ P0.38/hr)	16.64	
REDUCED BENEFITS		
Single Plow Yield (111 kgs @ P0.43/kg)	47.73	
SUB TOTAL DECREASES		77.16
NET GAIN		19.41

Source: Adapted from Worman [1987].

(b). The partial budget may indicate that a new technology is "better" than an existing technology, but not the "best" level at which to use the new technology. For

example, feeding a supplement to dairy cattle is better than feeding no supplement, but partial budgeting will not tell how much supplement it is most profitable to feed. [Caldwell, Taylor and Walecka, 1987: p. 267].

11.3.5 MARGINAL RETURNS ANALYSIS

Marginal returns analysis (MRA), like budgeting and average returns analysis, deals with the preparation of cost and returns estimates (or projections) for individual enterprises on a given farm. The preceding two sections interpreted average returns from three types of budgets which -- when based on accurate information about production relationships, costs, and prices -- can assist the farmer in estimating the profitability of an enterprise (enterprise budget), a change in the enterprise (partial budget), and the entire farming operation (whole-farm budget), given levels of variable inputs. However, budgeting and average returns analysis by themselves do not give the economist a broad enough picture of how outputs and returns are affected as the given levels of variable inputs change, other things being held constant.

MRA complements budgeting by adding insight into the physical and economic relationships affecting profitability. In particular, MRA helps in the selection of the best (most efficient and profitable) allocation of resources for a given enterprise, by determining the amount of variable inputs to combine with one or more fixed resources. The key difference between MRA and budgeting is that MRA predicts the profitability of an enterprise (or enterprises) as levels of variable inputs change, while profitability (average net return) represented in a budget is contingent upon given input levels. In short, MRA expands the scope of budgeting by considering changes in variable inputs.

We have not used marginal returns analysis extensively in farming systems research in Botswana. The reason for this is that MRA requires a significant amount of data, using different levels for each important variable in a trial. Some of the RMRI trials could serve as a basis for marginal returns analysis if it is conducted with sufficient variation in the important inputs, and the trials are conducted in a number of different years and locations. Generally in RMRI work, we have used only a few levels for the important variables and the trials have not been conducted over many different environments. RMFI trials are even more limited than RMRI trials in the number of inputs which are varied, and we do not normally collect data on inputs for FMFI trials, so neither of these trial formats provides sufficient data for marginal returns analysis.

Although marginal returns analysis has not been used extensively in farming systems work in Botswana, we do include this section on the technique as it is potentially a very useful analytical tool.

11.3.5.1 Principles Of Marginal Returns Analysis

The term "marginal" implies change, specifically the rate of change between two parameters. Technical scientists, such as agronomists or animal scientists, are often concerned with marginal physical products (MPP). The MPP is the additional output resulting from adding one more unit of input, i.e., how many kilograms of maize are received from adding one additional kilogram of fertilizer. Economists are often concerned with the addition to total revenue when one more unit of the input or factor is employed. This is the marginal revenue product (MRP) of an input. The profit maximization point is where the MRP equals the marginal factor cost (MFC), that is, the cost of using one additional unit of the input. Detailed discussion of these concepts can be found in any economics principles text book.

11.3.5.2 Minimum Acceptable Rates Of Return

This type of MRA is often used to study experimental data or data from a group of similar farms where a number of levels of crop and livestock productivity are available. Net returns taken from enterprise budgets for different levels of variable inputs are used to calculate rates of returns for each level of the variable inputs. After the rates of return are calculated for each level of variable inputs, they can be compared with the minimum rate of return a farmer is willing to accept from that enterprise. The rate of return from an enterprise can be calculated as:

$$r = \frac{\text{change in income above operating costs}}{\text{change in total operating costs}} \times 100$$

Where r = the rate of return (expressed as a percentage). Note that r calculates the rate of return to variable inputs only, not variable and fixed inputs.

Using the information contained in Table 11.8, and arbitrarily changing some of the gross receipt and operating cost parameters, provides a good example of how calculating rates of return can determine the relative profitabilities associated with each change in the enterprise.

In Table 11.11, Column 1 describes the change taking place in the double plowed sorghum/millet enterprise depicted in Table 11.8. Column 2 contains the new gross receipts associated with the change. Column 3 contains the new total operating costs figure, and Column 4 contains the new income above operating costs (net average return). Column 5 presents the rate of return associated with each change.

As Table 11.11 indicates, the range of rates of return can vary greatly, depending upon which changes are assumed.

The economist or farmer should decide on a minimum acceptable rate of return which he/she compares with the rates calculated in Table 11.11, thus determining whether or not the rate of return for the enterprise is acceptable given the change in the enterprise. Normally, the interest rate offered by banks (for savings accounts) or the expected rate of inflation over the planning period are used as minimum acceptable rates of return. These rates represent expected returns from the farmer's next best investment alternative, or in other words, his opportunity cost of investing in the enterprise.

TABLE 11.11: RATES OF RETURN ASSOCIATED WITH VARIOUS CHANGES IN THE BASIC ENTERPRISE BUDGET FOR DOUBLE PLOWED SORGHUM/MILLET PRODUCTION ON ONE HECTARE, FRANCISTOWN AREA, 1985-87

DESCRIPTION OF CHANGE	NEW GROSS RECEIPTS	NEW OPERATING COSTS	NEW INCOME ABOVE OPERATING COSTS	r
1. No change in basic costs and returns	P 98.04	P 59.72	P 39.52	66.18%
2. Price of sorghum/millet increases to P 1.50	342.00	59.72	282.28	472.67
3. Yield decreases to 100 kg/ha	43.00	59.72	-16.72	-28.00
4. Labor costs increase to P0.75 per hour	98.04	116.70	-18.66	-15.99

Source: Adapted from Worman [1987].

As indicated in Table 11.11, the first two rates of return -- for "No change in basic costs and returns" and "Price of sorghum/millet increases to P1.50" -- are extremely high, probably higher than a realistic minimum acceptable rate. Therefore, under these circumstances, the

farmer's investment in double plowing one more hectare of sorghum/millet is highly profitable. The last two rates of return -- for "Yield decreases to 100 kilograms/hectare" and "Labor costs increase to P0.75 per hour" -- are extremely low. In fact, they are negative because "Income above operating costs" are negative. In these two cases, the farmer's rates of return, given the changes, indicate that he is actually paying interest on the investments in double plowing rather than receiving returns.

11.3.5.3 Equimarginal Returns

Equimarginal returns analysis augments the minimum acceptable rate of return analysis in a significant way -- it determines the best allocation of one or more inputs over one or more enterprise(s) for the whole-farm [Calkins and Dipietre, 1983: p. 55].

To perform equimarginal returns analysis, the economist must have cost and returns information for two or more enterprises in the whole-farm operation; and information on how the returns and costs change for each enterprise as the level of investment in them changes. Because enterprise data is limited for Botswana when considering various levels of capital investment in cropping and livestock enterprises, a hypothetical whole-farm situation is depicted in Table 11.12.

Table 11.12 lists the average returns (net of labor costs only) realizable by investing P100.00 increments in each of the three activities. Reading across the first row, one hundred Pula invested in sorghum returns P500.00, while the returns to that same one hundred Pula are P900.00 and P300.00 for livestock and smallstock, respectively. The column totals give the total average returns realizable if all eight investments were taken in each enterprise, to the exclusion of the other two.

Assume that only P500.00 of capital is available to the farmer for investment in his overall farm operation. Allocating each P100.00 to the activity producing the greatest returns would result in placing the first three investments in livestock activities. The fourth investment would go to sorghum production, and the fifth to livestock. The final result is P400.00 invested in livestock production, and P100.00 in sorghum production, with total average returns to capital equalling P3,350.00 -- P500.00 from sorghum and P2,850.00 from livestock production.

TABLE 11.12: HYPOTHETICAL RETURNS FROM INVESTMENT OPPORTUNITIES REQUIRING P100.00 INCREMENTS OF CAPITAL

INVESTMENT	AVERAGE RETURNS FROM SORGHUM	AVERAGE RETURNS FROM LIVESTOCK	AVERAGE RETURNS FROM SMALLSTOCK
1	500	900	300
2	430	800	300
3	400	700	300
4	350	450	200
5	310	320	150
6	250	200	100
7	150	100	80
8	80	80	70
Total average returns from all eight investments (P)	2,490	3,550	1,500

Source: Adapted from Calkins and Dipietre [1983].

As shown, equimarginal returns analysis is especially suited for situations where cost and

return information for more than one enterprise is known, and for farmers who are considering various levels of investments in each enterprise. Allocating each investment increment to the highest return assures the farmer of achieving the highest level of total net income for all enterprises [Calkins and Dipietre, 1983: p. 56].

This section has discussed marginal returns analysis, both in terms of how it augments budgeting and average returns analysis, and how it differs from them. Like budgeting and average returns analysis, MRA deals with the preparation of cost and returns estimates, or projections, for individual enterprises on a given farm. These estimates, in turn, help the economist select the best allocation of resources for a given enterprise, by determining the amount of variable inputs to combine with one or more fixed resources. Unlike budgeting and average returns analysis, MRA predicts the profitability of an enterprise (or enterprises) as levels of variable inputs change.

11.3.6 RISK ANALYSIS

11.3.6.1 What Is Risk?

The previous three sections introduced several economic concepts, and demonstrated how these concepts may be utilized in preparing cost and returns estimates for individual enterprises on a given farm and/or the entire farm operation. As shown, budgeting and average returns analysis are tools which we can use to estimate profitability, given levels of variable inputs. Marginal returns analysis extends interpretation of profitability by considering how the estimated profitability changes as levels of variable inputs change.

Unfortunately not all inputs are under the farmer's control. In Botswana one of the most critical inputs for rainfed agriculture is moisture. There is a great deal of variability in rainfall between years, within years, and even between plots in the same village. This highly variable rainfall introduces a great deal of risk and/or uncertainty into the farming system. There may be other sources of risk as well such as uncertainty about the availability of seed or traction. Farmers consider risk in their farming system and make adjustments to compensate. One of the traditional methods of addressing risk is to plant a large number of plots over a period of time in order to take advantage of the rains that do come. Another risk reducing mechanism is to keep the investment of labor and cash in arable agriculture as low as possible. Thus the farmer will not weed a plot if in her/his opinion that plot will fail.

By looking at the distribution (range) of returns from experiments it is possible to obtain some information on how risky a particular technology may be. There are several simple tools for looking at the distribution of returns which can help in examining the question of risk. By comparing returns associated with various levels of inputs, marginal returns analysis can be used, in a limited way, to account for the risk a farmer assumes by investing in a given technology or set of technologies (see Table 11.11). MRA is limited in assessing risk because it only looks at changes in variables over which the farmer has control, while most of the risk comes from other factors such as weather.

Partial budgets can also be used to assess risk when a sensitivity analysis is included showing expected net gains due to changes in certain variable inputs (outputs) and/or their prices (see Table 11.10).

In the real world, no two farmers have the same attitude toward risk. Some are more inclined to take risky actions (before, during, or after the cropping season) with the ultimate hope of receiving a larger return on their investment of labor and cash. Some are less

inclined to do so. When one interprets farmers' risk attitudes, it is important to assume that they realize there may be a trade-off between getting a greater return from a technology and assuring that there is stability in the return, i.e. that there are few years with little or no return.

Farmers are generally grouped into three categories when considering their attitudes toward risk. These groups are:

(a). ***Risk Averse.*** Farmers who are willing to sacrifice high expected yields and returns in order to keep the risk of low income and loss at a minimum. This type of farmer is conservative in his/her approach to decision making.

(b). ***Risk Preferring.*** Farmers who will go after the highest yields and expected returns, even though there is a good possibility that they will receive a low income or suffer a loss in many years. This type of farmer is liberal in his/her approach to decision-making.

(c). ***Risk Neutral.*** Farmers who chose the technology with the highest expected yield or return, without considering the potential for losses.

Farmers may fall into different groups depending on the season, the amount of resources available to the farmer at that particular time, the magnitude of the cost, and the potential gains and losses from a given technology. When FSR workers interpret risk for technologies it is important to remember that farmers will look at risk differently, and so may fall into different recommendation domains based on their attitude towards the risk involved in a particular technology.

11.3.6.2 Types Of Risk Analysis

Generally a farmer will have some idea of the risk of crop failure under the cropping system he/she currently uses. When considering a shift to a different cropping system the farmer usually thinks not only of the cost of additional inputs (labor and cash), the potential net gain in returns (whether considered in terms of yield or cash value), but also the increased or decreased risk of having a crop failure. If farmers think there will be an increased risk under a new technology, they will often want to see a large net gain from the shift to compensate for the increased risk. An increase in yield or net returns of 30 percent over the existing technology is probably the minimum increase that most farmers will consider acceptable before they adopt the technology. The opposite is also true. A perceived decrease in risk will often induce farmers to shift technologies even if the gains from doing so are small.

Actual measurement of farmers' risk attitudes is very complex, and not practical because the attitudes are always changing. Thus we have used methods for estimating risk which are based on the actual data collected in experimental work, rather than trying to measure farmers' attitudes toward risk.

There are three relatively simple ways of analyzing risk that depend on the outcomes from trials of new technologies which are compared to existing technologies. Of particular interest is the way the outcomes are distributed, i.e., if the outcomes are graphed from lowest to highest for each technology, what is the relationship between the graphs. The three types of risk analysis to be discussed are: stochastic dominance, safety first, and other distributional analysis. Because these are all based on the same distribution of outcomes, there is a strong relationship among these analyzes and in some situations they are the same.

11.3.6.3 Stochastic Dominance[9]

The stochastic dominance rules for selecting technologies are based on very simple assumptions about the utility function of farmers. The first stochastic dominance condition is a result of the assumption that the farmer would prefer more to less, everything else being equal. Implementing the first degree stochastic dominance criteria is relatively simple. Experimental outcomes for two technologies, A (a new technology) and B (the existing technology), are ordered from worst to best outcome. A pairwise comparison is then made of all outcomes. If the outcomes from technology A are never less than the outcome from technology B and are greater than the outcomes from technology B at one or more points, then technology A is said to dominate technology B.

If we compare all technologies two at a time we can determine those which are dominated by another technology. When this comparison is done for all pairs we will have three categories of technologies: those that are not dominated by another technology, those that are dominated by another technology, and those which are not determined. This happens when the lines cross and neither technology dominates. Those technologies which are not dominated are said to be first degree stochastically efficient. Those technologies which are dominated are said to be inefficient and should never be chosen by a farmer who prefers more to less.

The first degree stochastic dominance comparison can be done by graphing the cumulative distribution function (CPDF) versus the outcomes for each technology and visually inspecting the resulting lines to determine which technologies are efficient. Figure 11.2 is an example of a first degree stochastic dominance comparison using a graph of the CPDF for net returns to single plowing and double plowing taken from ATIP trials' data. The CPDF is on the X-axis, and the net returns per hectare in pula is on the Y-axis. To be dominant, the double plowing line must be everywhere equal to or above the single plowing line. The lines on Figure 11.2A are hard to see at the lowest end, so Figure 11.2B is an enlargement of the lowest end of the lines. As can be seen, the lines cross and the double plowing line falls below the single plowing for two observations. Thus it is not possible to conclude that double plowing is dominant by first degree stochastic dominance.[10]

The first degree stochastic dominance test may not distinguish between two technologies. If it does not, then a second test can be run. The second stochastic dominance efficiency criterion includes the additional assumption that the farmer is averse to risk. This means that the farmer would rather have a sure small increase in returns than a large uncertain increase in returns. The implementation of this decision criterion is slightly more difficult. Areas under the cumulative probability density functions, developed for first degree stochastic dominance analysis, are compared at all income levels relevant to the technologies. If the area under the CPDF for technology A is never greater than the area under the CPDF for technology B, and is less than the area for B at one or more points, then technology A is

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[9]. This discussion is taken from Schurle and Worman [1990].

[10]. The normal presentation of this type of graph would be with the cumulative probability density function on the Y-axis and the net return on the X-axis. Unfortunately Lotus 123 does not allow for multiple X-axis lines, only multiple Y-axis lines, so the graph is rotated 90° from the usual presentation. This does not effect the results, only that a dominant technology must be everywhere equal to or above the dominated technology, rather than being to the right as is the usual case.

FIGURE 11.2: EXAMPLE OF FIRST DEGREE STOCHASTIC DOMINANCE ANALYSIS, DATA FROM RMFI DOUBLE PLOWING TRIALS, ATIP FRANCISTOWN AREA, 1985-87.

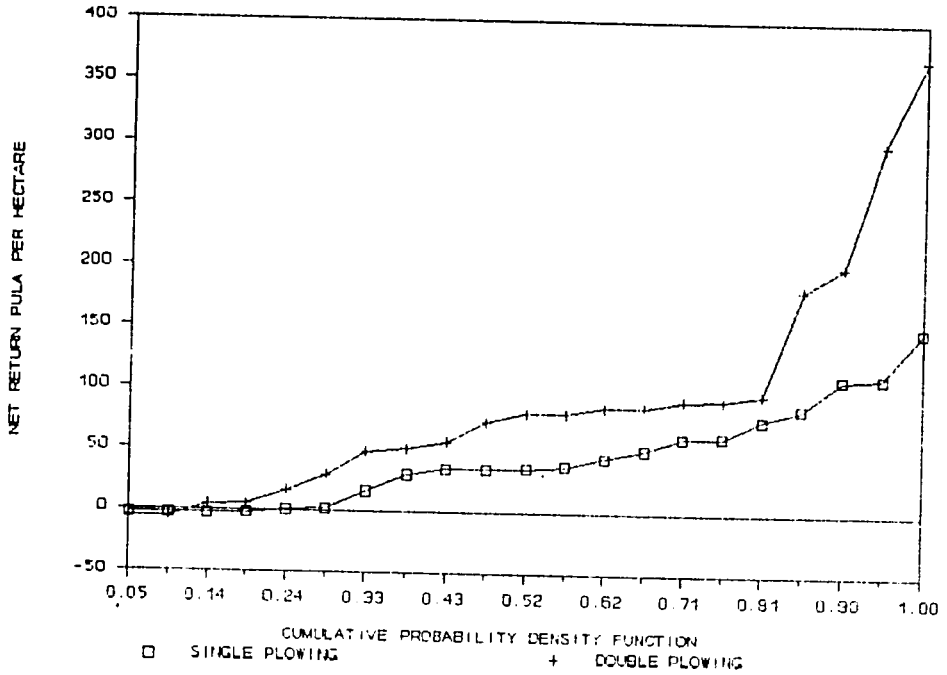

FIGURE A

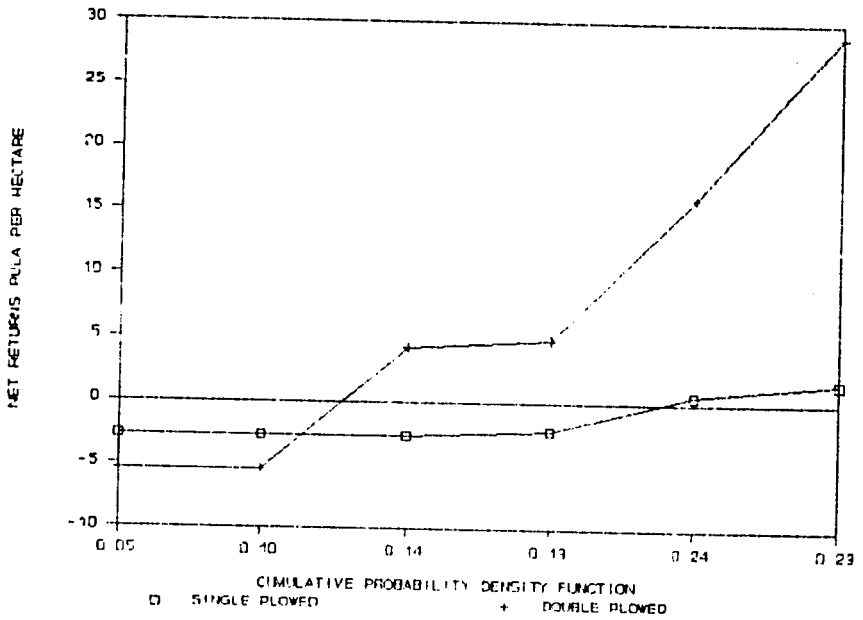

FIGURE B

said to be efficient.[11] In other words, technology A would be selected by anyone who prefers more income to less and who is risk averse.

Stochastic dominance comparisons of cumulative density functions for different technologies must be made on the same base unit. In other words, one cannot compare the CPDF for one technology for a hectare with the CPDF for another technology for a unit of labor. The base units must be the same. In addition, the correct base unit must be used. Choice of the correct unit may be subject to some debate. Where feasible, it would seem best to consider the entire farm as the base unit. This, however, is not feasible for most instances when using research plot data. The base is frequently a hectare when land is a limiting factor. In Botswana, land is not the limiting factor in many instances, so it may be more reasonable to use a unit of labor. We have used the net return per hour of labor, but it would also be possible to use the net return per hour of labor for those periods when labor is most limiting, for example, during plowing.

Development of stochastic dominant efficient technologies should result in voluntary adoption because of the perceived improvements in the distribution of incomes, providing the technologies will fit well within the constraints of the farming system.

Two necessary, but not sufficient conditions for a preferred technology are:

(a). That the worst outcome must be better, and
(b). That the average outcome must be higher.

For a new technology which requires more inputs of labor or cash than the traditional technology, the condition that the worst outcome be better for the new technology is hard to achieve in Botswana where drought is frequent. This is because a complete crop failure will always mean a lower outcome for the technology which requires more inputs. Farmers who are risk averse will not want to adopt such a technology, but a risk preferring farmer would not necessarily worry about the worst outcome if the average outcome was higher. One potential way to overcome this problem is to provide a subsidy for a new technology which will assure that the worst outcome for the new technology is at least as high as the worst outcome for the old technology. Another possible way would be to consider the average of the five worst outcomes under both technologies as the worst situation, since most farmers would probably not consider just the single worst outcome, but would consider a range of worst outcomes.

11.3.6.4 Safety First Analysis

Most farmers are not only concerned with the highest yield, or return, they can get from a technology, but also what are the possibilities of getting little or no yield or return, and in fact suffering a loss. Safety first analysis looks at the results of experimental trials comparing two technologies, a new technology and a traditional technology, and asks which technology will meet a chosen minimum standard -- a minimum yield or a minimum income -- most often. Alternatively, safety first can indicate which technology will produce a loss the least often. For some farmers it is very important to have a certain amount of grain produced or the family will go hungry. For this type of farmer it does not matter how high a yield may be possible with a new technology, if his/her family will go hungry more often

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[11]. Using the rotated graph in Figure 11.2, the areas being considered would be to the left of the two CPDF lines. Incidentally, there is a Lotus 123 spreadsheet program available in Schurle and Worman [1990] to do this type of analysis.

under the new technology than under the old they will not switch.

Strictly speaking, a safety first analysis is the probability (percentage of the time) that a technology exceeds a specified output level. Two or more technologies can be compared, and the one which produces at least the desired output level the highest percentage of the time is preferred. A second way of looking at the same issue is to determine the percentage of the time that a technology falls below a specific minimum level that must be reached. Table 11.13 provides some data on the percentage of times that some factors, considered in single plowing and double plowing trials, were above the specified minimum. It appears that double plowing was generally better in this measure of risk than single plowing.

TABLE 11.13: SOME INDICATORS OF RISK, ATIP FRANCISTOWN RMIT DOUBLE PLOWING TRIALS, 1985-87

VARIABLE	N	MEAN	MEDIAN	% < MEAN	% > MINIMUM
Yields kg/ha:					
Single plow	20	110	88	60	70 kg/ha
Double plow	20	228	191	70	65
					75
Net return to total labor (P/hr):					
Single plow	20	0.47	0.42	55	P 0.38/hr
Double plow	20	0.57	0.40	60	55
					65
Net return to traction hours (P/hr):					
Single plow	20	1.64	1.07	60	P 0.38/hr
Double plow	20	2.12	1.15	75	50
					65

Source: Worman [1987].

11.3.6.5 Other Distributional Analysis

While both of the above risk analysis tools use the distributions of trial outcomes in examining risk, it is also helpful to look at some of the traditional measures of distributions to get clues as to how the technologies will be assessed for risk. The traditional way of reporting trials data is to look at the arithmetic mean. The technology with the greater mean yield is generally preferred. However, one year of very good results, combined with several years of very poor results may give a higher mean than several years of average results. And a farmer may prefer to have a steady return rather than one which fluctuates a great deal. Thus it may help to look at the data in more depth.

One way to provide more information to the farmer is to compare the median, which is the value that is half way between the highest and the lowest value, with the mean. If the median is less than the mean it indicates that the farmer will receive less than the mean return more than half of the time. It may be helpful to look at how much difference there is between the mean and the median. If there is little difference, then the farmer will receive close to the mean most of the time. If there is a lot of difference, it may indicate that there are a few really good returns for the technology and many rather poor ones. Actually graphing the distribution can help in determining what is happening in the relation of means and medians.[12]

Another potentially useful measure is the percentage of the time that a farmer can expect to receive a yield or return less than the mean yield or return. If this percentage is high, it generally indicates a situation of a few good and many poor yields or returns.

[12]. These are some indications of the skewness of a distribution.

Table 11.13 provides information on the mean, median and percentage of times the yield or return was less than the mean for some single plowing and double plowing data. While, in general, both the mean and the median were greater for the double plowing, indicating a possible overall advantage to double plowing, the percentage of the time that single plowing is less than the mean is smaller than for double plowing indicating that double plowing may be somewhat less stable.

FSR workers may want to consider using an average of the five lowest yields rather than just the lowest yield for comparison purposes. In the case of the data from Table 11.13 the lowest yield for both single plowing and double plowing was zero, i.e., no yield. This produced a net loss of F2.70 for single plowing and a net loss of P5.70 for double plowing. Comparing an average of the five lowest yields gave an average of 1.8 kilograms/hectare for single plowing (average return of minus P1.97) while the five lowest yields on the double plowing averaged 19.4 kilograms/hectare (average return of P2.90).

11.4 SOCIAL ANALYSIS

11.4.1 WHAT IS SOCIAL ANALYSIS?

Farmers make the decision to use a new technology. There are many factors which go into the farmer's decision. Some of the factors are technological, i.e., increased yield, reduced pest problems, etc. Technological analysis is based on the response of plants and animals being tested. Other factors are economic, e.g., will the new technology provide a greater return to labor invested in the enterprise. In addition to the technological and economic factors, there are a whole set of factors influencing a farmer's decision to use a technology which are related to social considerations such as who makes decisions concerning the technology, who actually does the work, or the existence of community taboos concerning a practice. Social analysis deals primarily with "why" farmers do or do not do certain things. Social scientists observe people's behavior and then offer reasons for why people behave as they do. The social analysis goes beyond the economic evaluation of the farm as a business and looks holistically at the entire farm operation and its setting in the wider community. In many ways the goal of the social analysis is to ensure that the farmer's perspective is included in the analysis.

Social analysis can take several forms. Often it is based on researcher observation and experience. It can be based on a rapid informal survey conducted by team members, it can be a based on a formal survey, it can be a continuation of economic analysis (i.e., where economic analysis may stop with calculating the cost of labor inputs to a trial, the social analysis may use the same data and examine who performs the labor, and how it interacts with other labor demands for that person or persons), or it may be based on conclusions drawn from informal talks with farmers while visiting the fields.[13] Because much of the information necessary to make social evaluations is gained by observing farmers, it is generally not possible to wait until the end of the trial to begin collecting information to undertake a social analysis. Some of types of questions which we have found useful to ask in determining what type of information to collect are:

(a). Who does each task in the production cycle? Who decides which tasks should be

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[13]. It may also be based on an indepth village case study where the researcher resides with the people concerned for a period of time, to build up an atmosphere of mutual trust and understanding, which is necessary in order to obtain certain types of sensitive information.

done?

(b). Does the proposed technological solution require more labor or resources than are required under traditional production methods? How do households meet these additional needs?

(c). Does the technology being tested require new farmer skills? Are they difficult to learn?

(d). What other activities do the farm household members perform in addition to those directly related to the technology being tested? Does the experimental technology compete against other important uses of household labor, time or resources?

These types of questions can be asked for most trials involving significant labor inputs. Surveys and other kinds of studies may require different types of questions depending on the objective of the study. There are certain types of sociological studies which are fairly specific, such as nutrition studies or adoption studies, and have their own methodologies.

Social science evaluation looks at differences between what the researchers anticipate the farmers will do in a trial, and what they actually do. It is important to understand why farmers make changes in a trial, as well as what are the changes. The important thing to remember in social evaluation is to ask "Why?" every time one asks the question "What is going on?"

From the farmer's viewpoint, seven key questions can be asked during the evaluation of a technology. Some of these can be answered with technical or economic information, but most have a social component. They need to be answered if the researcher is going to really understand what the farmer is doing and why. The questions are (see Section 5.4.2):

(a). Is the problem to be solved important to farmers?
(b). Do farmers understand the trial?
(c). Do farmers have time, inputs, and labor required by the improved technology?
(d). Does the proposed technology make sense within the present farming system?
(e). Is the mood in a region favorable for investing in new technologies or crops?
(f). Is the proposed change compatible with local preferences, beliefs, or community sanctions?
(g). Do farmers believe the technology will hold up over the long-term?

11.4.2 SOME EQUITY ISSUES

Because most farming systems projects have as one of their goals to increase the equitable distribution of benefits from farming to all farmers, there are a number of equity issues that are usually addressed by social analysis. Four of these will be discussed here.

11.4.2.1 Inter-Household Equity

A new technology may require more labor, more draft, or a change in the labor and draft patterns. It may entail other changes in the overall farming system practiced by the farm family. Because the farm family does not operate alone, i.e., the family is part of an extended family and a village, these changes may have implications for the family's obligations relative to other family members and village organizations. For example, if a family traditionally provides draft power for members of the extended family who do not have draft, or if the family participates in some type of labor sharing scheme in the village,

a change to a new technology that affects these relationships can decrease draft or labor available to others. This is an inter-household equity issue and must be considered because even though the new technology may be a gain for the farm family, it may produce a net loss in the community by adversely affecting others. This type of issue does need to be considered in evaluating a new technology because it may cause farmers not to adopt a technology which is technically superior because it is socially a disaster.

11.4.2.2 Applicability Of Research To All Household Heads

The impact on both male and female headed households must be considered. This is generally a major gender issue and it is important to know if the on-farm research is equally applicable to both female and male farmers. In some cases, farming systems teams may emphasize technologies that are more applicable to male farmers than to female farmers. This may be because male farmers have more resources than female farmers, or because male farmers are selected by the team to be cooperating farmers. The team should assess whether the technologies being studied are addressing the real issues of female farmers, and whether there are a representative proportion of female farmers among cooperators and in survey research. In many cases the female farmer is also a very limited-resource farmer so that technologies which address the constraints of limited-resource farmers will address the constraints of female farmers, and vice versa.

Ensuring that a farming systems program is addressing the needs of female farmers is often not an easy task. The inclusion of gender sensitive analysis in the diagnostic stage is important in laying a foundation for including problems of particular importance to female farmers in the final research program. Constant observation by researchers of what is happening in the field can also help in identifying situations where problems of female farmers are not being adequately researched.

Female farmers are not necessarily a homogenous group.[14] For example we have identified three general groups of female farmers. These are:

(a). The farmer who is unmarried (female head of household) and has never been married. This person is usually young, has several small children, and has very limited resources.

(b). The female household head who is a widow and may have considerable resources from her marriage.

(c). The female headed household which is a defacto female headed household where the husband is absent, usually at off-farm employment, and the female makes the majority of agricultural decisions. In this case there may also be considerable resources at the farmer's disposal.

For many purposes the latter two categories of female farmers will benefit from the same types of technologies as the male farmers, and the best distinction to be made becomes one of limited versus less limited resource farmers.

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[14]. Although it is not usually done, similar groupings can be made for male headed households. Generally we have found that it is more useful to look at resource groupings than to emphasis sex of head of household per se.

11.4.2.3 Intra-Household Equity

A second type of gender issue farming systems teams need to be aware of is the impact of the farming systems research within the household. This intra-household impact of technologies is important to consider because the costs and benefits of technologies do not always fall evenly on members of a household. Individual members of households tend to share some goals, benefits and resources; are independent on some, and in conflict on others. Family members are also members of other groups through which they can acquire resources or benefits and to which they have obligations.

Often agricultural programs and research treat the family as a unit. However, due to the traditions of male family members performing some agricultural operations (e.g., plowing and care of cattle), while female members perform other operations (e.g., weeding, bird scaring, harvesting, and smallstock care), the modification of the farming system by the introduction of a new element may have a different impact on each of the family members. For example, a plowing subsidy may have a positive impact on the male members of the family by providing cash income but a negative impact on the female members because of increased weeding labor due to larger areas planted. Also there is no assurance that the male who receives the cash subsidy will use this income to benefit the family.

Thus when evaluating the impact of a new technology or program it is important to consider intra-household issues in the areas of labor (whose work is decreased and whose increased), access to and control of non-labor resources (who receives the new resources and who uses them), and incentives to participate (what incentives are there for the various participants to modify or not modify their farming practices).

In the design and testing phases, gender issues can be addressed in at least three ways:

(a). Cooperators should be chosen so that female farmers are at least proportionally represented. Very limited-resource farmers, who often include female farmers, should also be adequately represented.

(b). The potential impacts of a technology or program within the household should be considered.

(c). Emphasis may be given to activities, such as weeding, which are traditionally performed by female members of the household.

11.4.2.4 Societal Versus Individual Consideration

This is often a question of sustainability or whether the new technology will maintain the productivity of the farms over the long-term. As has been pointed out, farming systems programs can often work with technologies that offer immediate benefits to the farmers but which may be destructive to the land and other resources in the long-run. Thus the technology is beneficial to the individual but not to society. If an analysis is made of the sustainability of a technology, this consideration will be addressed. At times it may be desirable to have a technology which is not sustainable in the long-term, as long as it is coupled with practices which will build long-run sustainability into the farming system. The example given earlier of tieing destumping to planting trees in hedges is a good example (see Section 5.5.2).

11.4.3 CONSUMPTION/NUTRITION CONSIDERATIONS

Consumption and nutritional questions are often not a major concern in a harsh environment

such as Botswana. The major concern is generally producing anything, not choosing between types of crops to produce. We do not usually have enough flexibility in the system to consider changes in the cropping calendar. There are, however, some potential ways to address nutritional issues. Three of these are:

(a). Increase the use of livestock products to change not only the composition of the diet but to address potential protein deficiencies at certain times of the year.
(b). Use of remittances or off-farm employment earnings to augment the diet available from on-farm activities and improve the nutritional balance of the diet.
(c). Increase the proportion of the farming effort which is used to produce pulses (beans) since they have a very good nutritional impact.

Generally there are three issues that need to be considered in the consumption/nutrition area when evaluating a new technology.

(a). It does no good developing a new technology, particularly a new crop variety, and then find that farmers do not like its consumption characteristics, i.e., color, taste, etc., and so will not use it.

(b). It is important to consider whether the introduction of a new technology, particularly a new crop replacing an existing crop, will have a detrimental effect on the farm family's nutrition.

(c). It is necessary to consider whether a new technology will increase or decrease the periods during the year when food is available.

There are at least three ways to approach the nutrition question.

(a). ***Simple Evaluation On Nutrient Content.*** A comparison can be made of different crops in terms of their nutrient contents, i.e., kilo-calories of energy, vitamins, iron, protein, etc. The nutrient values for various crops are available in references such as Leung, et. al., [1968].

(b). ***Net Nutritional Benefit (NNB) Analysis.*** Where a new food is likely to displace an older food a comparison of the factors mentioned in (a) can be made as in the following example where the sweet potato is being added to the diet and the cassava subtracted:

	Kcal	Vit A	Iron	Protein
100 gm sweet potato	105	1,705	0.56	1.65
100 gm cassava	-120	- 1	-3.60	-3.10
NNB =	- 15	1,704	-3.04	-1.45

(c). ***Nutrient Comparison Based On Percentage Of Recommended Amounts.*** The nutrient contents of foods can be converted to percentages of recommended amounts for good health such as the recommended dietary allowances (RDA) and proposed changes in foods can be examined for their impact on the family intake compared to the RDA.

In much of the farming systems work in Botswana, there has been an attempt to improve the production of traditional foods rather than introduce new foods or cash crops. Hence, the question of changing family nutrition by changing food patterns has not been an issue. However, it may be helpful to look at the food consumption pattern in terms of the nutrition it does supply, in relation to the recommended dietary allowances, to see if changes should

be made to improve the diets.

Consumption characteristics of new varieties can be analyzed using a chart of consumption characteristics such as the one presented in Form 11.2. If researchers have determined which consumption characteristics are most important to households, the new varieties can be assessed in relation to the current consumption preferences.

FORM 11.2: ARRAY OF CONSUMPTION CHARACTERISTICS

PRODUCT CHARACTERISTICS	CURRENT PRODUCT CHARACTERISTICS	TREATMENT CHANGES IN CHARACTERISTICS
PRODUCT REFERENCES:		
Color	_____	_____
Size	_____	_____
Shape	_____	_____
Density -- percent solids, etc.	_____	_____
Uses	_____	_____
PROCESSING CHARACTERISTICS:		
Ease of processing -- labor	_____	_____
Availability of inputs for processing[a]	_____	_____
EATING CHARACTERISTICS:		
Flavor	_____	_____
Texture	_____	_____
Color	_____	_____
COOKING CHARACTERISTICS:		
Texture	_____	_____
Time	_____	_____
Fuel/equipment requirements	_____	_____
STORAGE CHARACTERISTICS:		
Length of storage	_____	_____
Availability of storage inputs	_____	_____

a. Water, fuel, equipment, etc.

Food availability and accessibility can be assessed by using a food system calendar. The food system calendar is a listing of food availability by month for the current farming system. Crops to be added or subtracted can be entered on this calendar to determine if there is a shift in the availability of food under a new technology. In some cases the technology may be the introduction of a new food crop which will increase the number of months during the year when food is available, in others it may be the addition of a cash crop which reduces the time available for subsistence farming, and hence the periods during the year when food is available.

11.5 ASSESSING ADOPTION

11.5.1 WAYS TO ASSESS ADOPTION

One of the questions of interest to all members of a farming systems team is to what extent farmers are adopting recommended practices. Generally adoption analysis is performed on technologies which have been extensively tested in FMFI trials within a recommendation domain, and are ready for extension. The potential for adoption of the technology can be assessed by determining the adoption among the farmers who performed the final verification trials on the technology. It may also be of interest to know how many farmers are adopting technologies which they have been testing on a more limited scale as part of a research program.

It is desirable to know whether farmers are likely to adopt a particular technology before it is presented on a large scale through the extension system. If farmers are not willing to adopt the technology after the final large scale testing, it may need to be modified to

increase acceptability.

There are several ways to assess the " .ihood of adoption of a technology.

(a). The researchers make an assessment of the adoptability of each technology through their analysis of the technological, economic, and social factors which they think are important to farmers.

(b). Observations and discussions with farmers during the course of testing, particularly during a final large scale verification test, can give an indication of problems and provide the researcher with a qualitative assessment of the likelihood of adoption.

(c). A Formal End-Of-Season Survey of farmers can be used to assess their plans to adopt the new technology and determine any problems encountered.

(d). The best approach is to examine actual adoption by conducting a survey one or two years following the large scale testing of a technology to determine whether farmers who participated in the testing have actually adopted the practice and to what extent.

(e). A study of other farmers in the area, i.e., those not involved in the testing of the technology, can also be made to determine the extent of horizontal (farmer-to-farmer) diffusion.

Approaches (a), (b) and (c) are qualitative in nature and measure farmers' intentions either as expressed or deducted by researchers. Approaches (d) and (e) measure actual adoption and are quantitative in nature.

11.5.2 INDEX OF ACCEPTABILITY

One approach to quantifying the results obtained in approach (d) is to use the index of acceptability suggested by Hildebrand and Poey [1985: pp. 122-123]. To determine the index of acceptability for a particular technology, information is collected from farmers one or two years after they have participated in large scale testing of a technology. Farmers are asked if they are using the technology, and if so, on what proportion of the area of the particular crop for which it was recommended. An index of acceptability can then be calculated as follows:

$$I_a = (C \times A) \div 100$$

Where:

I_a = Index of acceptability

C = The percentage of the farmers interviewed who participated in the large scale testing and who were using the technology on at least part of the crop at the time of the interview.

A = From among those farmers who used the practice that year, the percentage of the area they planted with the new technology compared to the total area planted to the particular crop, i.e., the area planted to a new sorghum technology as a percentage of the total area planted to sorghum.[15]

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[15]. A modification of this would be to compare the area planted to the new technology to the total area which could **potentially** be planted using the new technology, thus taking into account limiting factors such as seed availability.

For example, if 150 farmers participated in the test of a double plowing technology, and after two years a survey found that 65 were using double plowing on at least part of the land they planted, then "C" would be 65 ÷ 150 = 43 percent. The average area planted using double plowing by the 65 farmers was 4.3 hectares. These same farmers planted an average of 6.1 total hectares. Thus "A" would be 4.3 ÷ 6.1 = 70 percent. The index of acceptability would be (43 x 70) ÷ 100 = 30.1.

A rule of thumb for interpreting the index of acceptability is that a technology has a good chance of being adopted if I_a exceeds 25 and "C" is equal to or greater than 50 [Hildebrand and Poey, 1985: p. 122]. This is a measure of acceptability to the farmer and does not reflect the impact of the technology. It is also important to consider the magnitude of both "C" and "A". It is possible to have a very low "C", indicating few farmers are adopting the technology, combined with a high "A", indicating that those who are using the technology were using it on a large portion of the land planted to the crop. This could be because a sub-group of the recommendation domain farmers find the technology particularly valuable, although it is not accepted by most farmers. This may also indicate that there are different recommendation domains present. The opposite situation, where a large number of farmers are using the technology on a small portion of the area planted to the crop, could indicate that farmers are still testing the technology and are not yet convinced that it should be "adopted". An additional survey in the following year may be valuable in assessing the adoption, or some modification may be necessary to promote adoption.

11.5.3 AN EXAMPLE OF AN ADOPTION STUDY FROM BOTSWANA

The index of acceptability procedure is designed for analyzing the adoption of a particular technology, usually for a single crop, for farmers in a specific recommendation domain. If it is used to measure adoption under other circumstances, such as a measure of spontaneous adoption on a range of new technologies, the interpretation of the results will be different, and the numbers suggested above will probably not be relevant. Instead the comparison of the index of acceptability between technologies, or by farmer characteristics (indicating possible recommendation domain delineations) may be of value. Such a study of spontaneous adoption was undertaken in the Tutume Agricultural District in 1989 [Worman, Williams, Tibone and Heinrich, 1990].

This study indicated that in 1988-89, 26 percent of the interviewed farmers had spontaneously adopted some of the technologies that ATIP had tested with them over the years. On average, 35 percent of the crop land planted by adopters was devoted to the new technology. Overall, the index of acceptability amounted to 9.2. Some additional results are:

(a). How complicated the technology is to implement affects the adoption. The relatively simple double plowing technology had an index of acceptability of 26 compared to the more complicated (requiring more management skills) row planting technology which had an index of acceptability of 14.

(b). As might be expected wealth influences adoption. Wealthier farmers were more likely to adopt with an index of acceptability of 19 for farmers owning more than 40 cattle compared to 0.7 for the poorest farmers, those owning no cattle.

(c). The environment in which the household operates is important in determining adoption with the farmers from the more progressive village having an index of acceptability of 19 compared to 1 for the farmers from the more traditional village.

11.6 USEFUL REFERENCES

Section 11.1:

Caldwell, Taylor and Walecka, 1987: pp. 3-22, 39-51.

Section 11.2:

Caldwell and Walecka, 1987: pp. 87-97.
Caldwell, Taylor and Walecka, 1987: pp. 55-80.
Gomez and Gomez, 1984: pp. 1-6.
Shaner, Philipp, Schmehl, 1987: pp. 325-335.
Section 11.2.1: Caldwell, Taylor and Walecka, 1987: pp. 81-99.
Section 11.2.2: Gomez and Gomez, 1976: pp. 458-477.
Section 11.2.3: Caldwell, Taylor and Walecka, 1987: pp. 101-258.
Gomez and Gomez, 1984: pp. 7-356.
Section 11.2.4: Caldwell, Taylor and Walecka, 1987: pp. 329-333.
Eberhart and Russell, 1966.
Hildebrand, 1984.
Section 11.2.5: Caldwell, Taylor and Walecka, 1987: pp. 313-323.
Gomez and Gomez, 1984: pp. 357-457.

Section 11.3:

Section 11.3.1: Caldwell, Taylor and Walecka, 1987: pp. 24-25.
Section 11.3.2: Shaner, Philipp and Schmehl, 1982: pp. 353-354.
Section 11.3.3: Shaner, Philipp and Schmehl, 1982: pp. 128-131.
Section 11.3.4: Caldwell, Taylor and Walecka, 1987: pp. 259-189, 371-376.
CIMMYT, 1988A.
CIMMYT, 1988B: pp. 9-28.
Mutsaers, Fisher, Vogel and Palada, 1986: pp. 150-156.
Perrin, Winkelmann, Moscardi and Anderson, 1983: pp. 3-4, 27-33.
Shaner, Philipp and Schmehl, 1982: pp. 125, 128-131, 353.
Section 11.3.5: CIMMYT, 1988A: pp. 30-54.
CIMMYT, 1988B: pp. 31-45.
Mutsaers, Fisher, Vogel and Palada, 1986: pp. 156.
Perrin, Winkelmann, Moscardi and Anderson, 1983: pp. 15-19, 23-25.
Shaner, Philipp and Schmehl, 1982: pp. 125-126, 132-135.
Zandstra, Price, Litsinger and Morris, 1981: pp. 142-147.
Section 11.3.6: Shaner, Philipp and Schmehl, 1982: pp. 131-132, 135-138.

Section 11.4:

Caldwell, Taylor and Walecka, 1987: pp. 299-377.

Section 11.5:

Caldwell, Taylor and Walecka, 1987: pp. 25-26.
Hildebrand and Poey, 1985: pp. 121-123.

CHAPTER 12: REPORTING RESULTS

12.1 WHO ARE YOU WRITING FOR?

Writing is work! When one writes obviously one wants someone to read the product of the effort. The audience may be one person or a thousand, but to be effective what is written must be written for the specific audience with which one wishes to communicate. If one does not decide what audience one is writing for, and get to know their needs, motivations, existing knowledge, language use, and the like, one cannot effectively communicate with them. For example, if one is writing for a busy administrator he/she will probably want facts and recommendations which can be used directly without further interpretation, and if the document containing this information is very long, the administrator will probably not be able to take time to read it. Thus it is important to know the audience.

There are several possible types of audiences for which researchers generally write [Kearl, pp. 186-186]:

(a). Other researchers in the same field. This is the predominant group for most scientific research because it is a group that can most easily understand what researchers are saying, and it is the group that decides their professional status. However, it may not be the group that most needs the results.

(b). Researchers in other fields. This is particularly important to farming systems researchers who are in a position to identify problems, and provide other information for on-station researchers in many disciplines.

(c). Policy makers, who need to know about trends in national development, redefinitions or diagnoses of national or sector problems, and information on impacts of policy measures.

(d). Planners who need a regular flow of information on the current status of national/regional activities and diagnoses of economic and social problems for use in planning.

(e). Implementers (project and program officials) who need tested technologies, information about target groups, or evaluation studies.

(f). Farmers and other specific groups of citizens looking for help in identifying problems, investigating possible solutions, and seeing the probable effects of alternative choices.

When writing, it is therefore important to consider the selected audience and tailor the interpretation of data and conclusions to their needs. However, the audience is entitled to know which conclusions are based on conjecture, and which are based on the relevant data. As scientists, there are obligations to report the results of a research project honestly and objectively. As a professional hired to provide information for resolving problems, one is also obliged to interpret the results in accordance with the needs of the audience. While the researcher is trained to understand complicated analysis and confusing data, the audience may not have this training, so it is up to researchers to report findings in a language that the audience will understand.

In many cases there are multiple audiences for research findings. Quite often it is important to prepare different reports for different audiences. Since farming systems teams in Botswana are part of the agricultural research structure, there should be a complete report of the trial or study for researchers who might wish to examine the findings in more depth, or replicate them. There may also be reports for meetings, proposed **Agrifacts** for the extension service, journal articles, and special data summaries for planners. While it is much easier to write in the jargon of ones profession because one is familiar with it, research results will have a wider audience if they are written in simple language.

12.2 TYPES OF REPORTS

Farming systems teams usually have several types of reports to prepare. The ATIP program has produced the following types of reports:

(a). Progress Reports
(b). Working Papers
(c). Miscellaneous Papers
(d). Reporting Documents (Annual Reports and Research Reports)
(e). Externally Published Papers

Since most teams are part of a larger farming systems program, they should prepare annual reports of their activities so that other members of the farming systems program and people at experiment stations can know how their research is going, even if it is only an interim report on a multi-year research project. We generally prepare a Progress Report every year on each of the major trials or activities undertaken, or include details of the data collected, and if it is a survey a copy of the survey form, as well as an interpretation of the findings. These are detailed reports intended for use by other scientists who are interested in the data. The ATIP Annual Report in addition to a summary of the year's activities also contains a work plan for the following year.

Another type of report we produce is the Working Paper. A Working Paper is generally a compilation of results for a trial over a number of years. The Working Papers are usually written at the end of a trial, and provide a summary of the data plus details on the findings. These reports often do not contain much detail and are designed for researchers, planners, policy makers, etc., who want an overview of trial work on a particular technology with more emphasis on conclusions and recommendations.

Farming systems teams often prepare special reports or papers which may be given at conferences or published in journals. These are generally brief papers discussing one specific subject and are published in a Miscellaneous Publications Series. When a report or paper is published outside of the ATIP organization, i.e., in a conference proceedings, it is entered as an External Publication, and copies are made for distribution. Other special reports could be summary research results for all trials conducted over a period of years with brief state-of-the-art accounts on each of the technologies tested during the period. These are produced as Research Reports.

12.3 HOW TO WRITE REPORTS

While the format chosen for a particular piece of writing will depend on the needs of the audience being addressed, we have generally used a format containing most or all of the following sections in our Progress Reports, Working Papers, and sometimes other

publications.

Title Page
Preface
Acknowledgements
Table of Contents, Lists of Figures and Lists of Tables (if a long publication)
Abstract
Introduction
Objectives
Justification
Methodology
Results
Summary and/or Conclusions
References
Appendixes (as appropriate)

While not all of these sections are included in every report, we have found that covering the relevant sections leads to a more organized and more complete report.

We also use tables extensively to present summaries of our data. We think that a well organized table can present the data in a much more concise and clear manner than can a written description. Figures are used to show relationships, summarize findings, and/or present a visual representation of some aspect of the report.

There are numerous reference books available that discuss writing reports and provide guidelines on grammar, etc. The following three books should be available in the DAR Library. The first publication contains writing guides which are particularly relevant to Botswana.

Esslinger, D., and G. Brandsberg, 1988. ***Communication Consultancy Report.*** Gaborone: ATIP, DAR.

Shertzer, M., 1986. ***The Elements of Grammar.*** New York: Macmillan.

Ross-Larson, B., 1982. ***Edit Yourself.*** New York: W.W. Norton.

See also DAR Annual Reports, The Bulletin of Agricultural Research in Botswana, ATIP publications, **Agrinews** and **Agrifacts**, for examples of styles and approaches.

CHAPTER 13: GUIDELINES ON SPECIAL FARMER LINKAGE ACTIVITIES

13.1 WORKING WITH FARMER GROUPS

13.1.1 WHAT IS A FARMER GROUP?

The term "farmer group" can obviously refer to any group of farmers who come together for any purpose. However, in the context of on-farm research in Botswana, the term Farmer Group is used to signify a group of farmers who come together to test and adapt new agricultural technology options, to discuss the results of those tests, and to identify on-farm needs for other technology options. These groups are composed of farmer participants, researchers and local extension personnel, and they generally meet at regular intervals throughout the cropping season. The farmers in these groups select the technologies they are interested in and test them under the FMFI format.

13.1.2 PURPOSE OF FARMER GROUPS

There are three main purposes for the formation farmer groups in on-farm research. These are:

(a). ***To Expand The Range Of Technologies That Can Be Examined In An On-farm Research Program.*** Trials that involve researcher management and supervision require the researchers to spend a good deal of time on field visits. This limits the number of technologies that a research program can test and evaluate. However, there are many technology options which may be useful to farmers, and there are others which have been developed on the research station which will need field testing before being released to extension. By using farmer groups and including farmers in the testing process, research programs can greatly expand the number of technology options being evaluated in the target area. For example, in the Francistown region, during the 1988-89 season, farmers implemented over 140 valid technology comparisons, and examined nine different technology options. These options included various types of equipment, agricultural chemicals, crop varieties and tillage systems.

(b). ***To Include Farmers In The Technology Development Process.*** One of the main reasons for conducting on-farm research is to include farmers in the technology development process. However, simply having researchers conducting trials on farmers' fields is not the most effective way to undertake this. In the farmer groups, the participants select the types of technologies they wish to test, they perform the tests for themselves, and they discuss and evaluate the various technology options with other farmers as well as with researchers and extension personnel. The two most important criteria used in judging new technology options are: how the technology performs under farmer management, and the farmers' joint evaluation of the various technology options. Additionally, at the regular meetings farmers have the opportunity to present their observations and opinions to research and extension personnel. Thus, through the farmer groups, the farmers become full partners in the technology development process.

(c). ***To Create A Forum For Direct Interaction Between Farmers, Researchers And Extension Personnel.*** One of the primary objectives of FSR is to create linkages between research, extension and farmers, at the field level. Farmer groups bring together farmers, researchers and extension personnel at the field level, in order to work together to develop applied technologies to increase farm productivity.

13.1.3 HOW FARMER GROUPS OPERATE

There are several ways for farmer groups to be organized. There are researcher-oriented and extension-oriented farmer groups. Although discussion in this handbook is mainly confined to researcher-oriented farmer groups, many of the points apply to extension-oriented farmer groups as well.

The groups are composed of researchers, extension personnel (from village, district and regional levels) and farmers. The groups are open to any village farmer who is interested in participating. At the first meeting of the group, researchers (both station-based and on-farm) discuss a wide range of technology options, addressing as many production constraints as possible. Farmers are also requested to raise questions about problems which they feel have not been adequately addressed. From the list of technology options which is thus developed, individual farmers select specific technology options they wish to test. However, across farms, trials of specific technology options are conducted according to a mutually agreed upon trial design. For example, a Cowpea Variety Trial, if selected for testing by ten farmers, is implemented using the same set of varieties, on the same size plots and with the same seeding rate at all ten locations. This allows subsequent statistical analysis. New equipment, small amounts of seed and required chemical inputs are provided by researchers. Additionally, the researchers visit each trial once during the season to verify proper implementation. Throughout the season, the farmers, researchers and extension agents meet, as a group, on a monthly basis. At these meetings, farmers discuss their progress with the trials, their observations and any problems encountered. Possible solutions to the problems are discussed by the group.

Researchers collect data on the dates of field operations, the crop and variety used (known because of the standard trial design and the use of researcher-provided seed). The type of equipment used is also recorded. At the end of the season, farmers harvest and sometimes research staff weigh grain yields and conduct End-Of-Season Farmer Assessment Interviews. These interviews are used to quantify farmer's opinions and perceptions of specific technology options (e.g., crop genotypes). Results are reported both to farmers and to other interested researchers.

More detailed descriptions of how the farmer groups are run are available elsewhere [ATIP 1987, 1988A and 1989; Heinrich, Worman and Masikara, 1988; Masikara, Worman and Heinrich, 1988].

13.1.4 BENEFITS OF GROUPS VERSUS INDIVIDUAL FARMER CONTACTS

There are many benefits derived from using the farmer group approach. A few of the more important ones are presented below:

(a). ***Efficiency*** Contacting farmers one by one requires a lot of travelling by research officers. Also, when dealing with individual farmers, researchers must explain their work and objectives, and the technology options they are interested in testing, many times over. By addressing farmers as a group, researchers not only save a great deal

of travel time, but they can explain their program to many farmers at once, thus saving time on explanations as well.

By holding regular group meetings with participating farmers throughout the season, farmers and researchers (and extension personnel) can discuss progress, problems, and farmers' observations, without the researchers having to visit each farm every month.

Thus by working with groups, instead of making a lot of visits to individual farmers, researchers save both time and government money that would otherwise be spent on fuel.

(b). ***Expanded Range Of Technologies Tested.*** When using the farmer group approach, researchers can work with many more farmers than when they work only with individuals. As a result of greater participation in the testing activities, many and varying technology options can be tested.

(c). ***Research-Extension Liaison.*** When researchers talk with one set of farmers and extension personnel talk with a another set of farmers, they may form different ideas about farmers' problems in a region, and the best solutions for those problems. However, if research and extension personnel work together at the field level, and meet together with large groups of farmers on a regular basis, this problem is reduced. Working together in the farmer group approach allows research, extension and farmers to come to a common understanding of the problems. If the same groups work together to test various technologies which address those problems, then all are able to see which technologies are useful and practical, and which are not. Furthermore, if extension personnel participate in technology development, they will be in a good position to later extend the same technologies to other farmers. Thus the farmer group approach provides a forum where researchers, extension personnel and farmers can meet on a regular basis to address problems in the field. This interaction can be of benefit to all participants.

(d). ***Group Dynamics And Immediate Feedback.*** An individual farmer may be reluctant to tell a researcher that a particular technology option is not good. It may also be difficult for an individual farmer to convince a researcher. However, if a group of farmers get together before a meeting, and all share a common opinion of a new technology, then it is likely that someone will raise the point during the meeting. Furthermore, if one farmer tells a researcher that a particular technology is not working, the researcher may just assume that the farmer applied the technology incorrectly. This will not happen if ten farmers at once explain that a technology option is not working.

Thus the effect of people being in a group tends to help communications (if the group is not too large), and provides a way for research and extension personnel to quickly obtain a practical assessment of any technology being tested. The groups also provide an opportunity for farmers to share opinions and observations among themselves, and to develop their own solutions to problems.

(e). ***Farmers Develop Their Own Production Packages.*** Farmers understand their own production problems and resource constraints better than researchers. Thus when farmers are able to select technology options from a range of options, and apply them where they wish, they often develop specific packages that are more practical than what researchers alone could have devised. Farmers may also find uses for technology items that researchers would not have considered. Thus farmers can have a lot of input into developing improved production systems.

(f). ***Farmers Teaching Farmers.*** The farmer group approach provides good material for field days. Because the trials are FMFI, the farmer who has implemented a trial is able to present it and explain it to other farmers. Farmers learn best from other farmers, so these field days can be very effective when a technology option is ready for extension.

(g). ***Flexible Response To On-station Research Needs.*** When large numbers of farmers are participating in the testing activities, it is very easy to introduce new technologies for field testing. For example, if the cowpea scientists at Sebele wish to get farmer evaluations of five new cowpea varieties, it is easy to introduce these to the groups, and find farmers who want to try them. It would not be as easy if the researchers had to implement the tests themselves in several locations. Thus the farmer group approach makes it easier for on-farm researchers to respond to the needs of on-station research programs for field testing of their new technologies.

13.2 CONDUCTING FIELD DAYS

13.2.1 BENEFITS OF FIELD DAYS

There are a number of reasons why field days are valuable:

(a). Inviting farmers and other agriculturalists to the field days is a good way of letting people know what the research program is doing. At the same time, field days can generate a lot of interest in new technologies within the farming community.

(b). Field days are useful for demonstrating how production can be increased through the use of improved technologies, and for getting farmers to think about how they can increase their own production systems.

(c). Field visits also provide participating farmers with a chance to show off their efforts, and to explain to the community what they are doing. These visits allow farmers outside the research program to participate in technology evaluation, and to add their comments and ideas.

(d). Field days provide an opportunity for on-station researchers to see how technologies they have developed are performing in the field, to listen to farmers' comments about the technologies, and to get ideas for improvements. At the same time, it gives members of the farming community an advanced look at some of the new technologies being developed, so that these technologies are not totally unfamiliar when they appear in the extension program.

(e). Field days can be a forum for getting on-station researchers, extension personnel and farmers together in the field to discuss specific problems and issues.

(f). Within ATIP we have also observed that field days tend to stimulate competitiveness among farming communities in terms of trying to out-produce each other.

13.2.2 AUDIENCES, TRANSPORTATION AND LOGISTICS

(a). ***Audiences.*** The nature of the audience can affect the types of presentations made at field days. For example, if a field day is held only for on-station researchers, the discussions would probably be conducted in a highly technical fashion, possibly by

the on-farm researchers themselves. However, if the majority of the audience is made up of farmers, the discussion would probably not be quite as technical (more applied in nature) and presentations of field trials might be done by the host farmers.

The field days conducted by ATIP have usually been aimed primarily at farmers within the Regions, but DAR and DAFS staff are always invited. The main objectives have been to allow people to observe the research program, and to stimulate discussion on specific topics.

(b). ***Transportation.*** Field days generally involve farmers in a district or districts coming to a particular village lands area to visit the fields, and to observe the trials being carried out. They may also be attended by DAR and DAFS officials.

Transport to the village in question, and around the fields, is generally not a problem for government officials, since they have access to government vehicles. However, it can be a major problem for limited-resource farmers. For this reason, generally the people responsible for the field day organize transport for the farmers as well (both ***to*** the village and ***around*** the fields). Large trucks, busses or four wheel drive vehicles can usually be obtained from the CTO, or the ministry pool for this purpose.

(c). ***Logistics.*** The success or failure of a field day depends on careful planning, good organization and constant checking of arrangements.

In order to have good attendance, the date of the field day must be decided upon well in advance. The same applies for the selection of an audience (who is to be invited). As soon as the audience is selected and the date set, the prospective audience must be informed of the date and invited to attend. The more time allowed for people to fix their schedules and organize their affairs, the more people will be able to attend. For example, it is not useful to invite people to a field day two days beforehand, because they will have planned other activities for that date.

Researchers must also work with farmers and extension agents to choose which fields to visit. This needs to be done early, to allow time to select the most appropriate fields. Within ATIP we have generally chosen fields which:

i. Represent the type of work being done,
ii. Show off promising results from improved technologies, or
iii. Provide examples of certain specific problems which can then become a focus for discussion.

If food is to be provided for the visitors, this also requires careful attention.[1] First it is necessary to estimate how many people will attend. Then it is important to decide on a menu. This is usually done together with farmers in the host community. After that the amount of food required can be roughly calculated (and it is better to have too much them too little). The organizers will have to purchase the food, find people to do the cooking, organize pots, plates, cups, knives and forks (usually

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[1]. Until now the meal at ATIP sponsored field days has been financed mainly by ATIP. However, other channels are now being explored For example, it might be possible for the farmers themselves to make contributions, for the meals to be financed and provided by the local Rural Training Center, or for the meals to be financed by ALDEP. With reference to the farmers making the contributions, this has, in fact, already been successfully done in some farmer fields in the Mahalapye area.

possible through the local primary school), identify a place for the meeting, and know what to do if it rains. All of this should also be done in advance.

In any case, whether food is provided or not, the organizers should ensure that water is available for people to drink in the field during the field tour. People will find it difficult to concentrate, and will be quite uncomfortable and want to leave the field, if they are allowed to become thirsty.

When planning a field day, it is necessary to develop a program or schedule for the day. This informs the participants about what is happening, and also allows the organizers to make sure that they allow sufficient time to cover all the important items. Before finalizing the schedule, shortly before the field day, the organizers should drive around to all the fields they expect to visit during the field day. This will allow the organizers to estimate the travel time required between the fields, and also ensures that there are no surprises on the day of the visits. Once this is done, the organizers can determine exactly how many field visits can reasonably be included.

Field days should start with an introduction of important visitors and an overview of the work the program has been involved in.[2] A discussion of the days schedule should also be included. Time should be allowed at the end of the day for some final discussion of what the visitors have observed, some concluding remarks, and thanks to the visitors for attending.

Some ideas on the length of time required for various activities, and items to include, are given in Section 13.2.4.

13.2.3 INVOLVING FARMERS AND EXTENSION PERSONNEL IN PLANNING AND PRESENTATIONS

Participating farmers and local extension personnel are an important part of any on-farm research program. They should therefore be included in the planning of all field days. Additionally, when people are involved in the planning of an activity, they become more interested in ensuring its success. Thus involving farmers and extension in planning field days can make those field days much more successful.

Farmers participating in the research program and local extension personnel can be involved in the planning in many ways, and can often contribute greatly. For example, they can help select the most interesting fields to visit. Local people in the village can welcome the visitors, and if food is to be prepared, they can help to organize a good location for eating, can help in organizing cooking and eating utensils, cooking and serving the food and cleaning up afterwards. In addition, farmers learn best from fellow farmers, so it is always an advantage, wherever possible, to have individual farmers present the trials on their land to the visitors. Extension personnel and researchers can always add to what the farmer/presenter has said, if they feel important points have been left out.

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[2]. There has been some discussion within ATIP about the problem of mixed audiences of researchers and farmers. The major problem revolves around whether the focus of such days should be on farmers or researchers. There is great value in researchers attending farmer field days, but care needs to be taken t[illegible] public discussion does not become dominated by researchers talking to researchers. [illegible]ier than farmers talking to farmers and to researchers.

Extension personnel may actually have items they wish to present during the field day, and may also help by assisting with trucks or vehicles for transporting farmers. Participation by extension personnel in field day activities generally adds to the overall program, and their participation will be more enthusiastic if they are included in the planning and implementation of the field day.

13.2.4 SUMMARY GUIDELINES FOR FIELD DAY PREPARATIONS

(a). The audience for the field day should be chosen early on.

(b). The date for the field day must be set at least a month ahead of time (and preferably even earlier), and the individuals invited should be notified as early as possible (at least ten days or two weeks before the date, though three to four weeks is preferable).

(c). The farmers in the village who are hosting the field day and extension personnel should be included in the planning.

(d). The headman of the village should be contacted about the field day early in the planning stage.

(e). About a week before the field day, researchers should visit all the fields that will be shown. They should check that all is in order, and estimate travel time between the fields.

(f). When making the schedule for the day, the planners should:

i. Start late enough so that most people can arrive in time;
ii. Allow for an opening session to welcome visitors, review the objectives of the day and present the schedule (about 30 minutes should be sufficient).
iii. Allow about 45 minutes to an hour for each field visited, plus whatever travel time is required between fields;
iv. Allow about 1 hour for lunch, if lunch is planned.
v. Allow about 30 minutes to 1 hour for a final discussion of the days observations and closing remarks.
vi. Allow enough time at the end of the program for visitors to be off the roads before dark.

(g). The organizers should be conscious of possible dehydration occurring and have ready supplies of water on hand.

(h). Whenever possible, the organizers should have individual farmers present their own field plot work.

13.3 FARMER TRAINING WORKSHOPS

13.3.1 PURPOSE OF FARMER TRAINING SESSIONS

Generally, farmer training is offered as a response to an identified need. For example, in the Central Agricultural Region, farmer training has been centered around row planting. Based on information from both research and extension it appeared that although the number

of planters purchased had tripled, there was very low actual usage. Additionally, the farming system team had experienced difficulty in testing options that required the use of the planters. Therefore, it was considered important that hands-on farmer training be introduced.

13.3.2 HOW TO ORGANIZE TRAINING

Since it is not possible to discuss how all training should be organized, we will provide some general guidelines based on our experience in organizing the training in row planting techniques.

The requirements of such a field course are to:

(a). Prepare the plot where the training will take place.

(b). Invite at least two farmers from each of the extension areas, and the area AD. It is important to have those responsible for row planting operations present at the workshop.

(c). Work with the AD and the farmers' committee in the village where the training session will be held.

(d). Make sure the village head is informed and invited to officially open the event.

(e). Arrange accommodation. If no accommodation is available organize for tents to be erected at an appropriate location, that is, where water and toilet facilities are accessible.

(f). Organize the purchase of food, etc., and for meals to be prepared.

(g). Prepare a schedule of the training program, and invite those individuals involved in the training. Since farmers benefit more from practical than theoretical sessions, more time should be devoted to hands-on training. The following is a list of practical aspects that could be included in the training program:

i. Show farmers how the different planters operate, with particular emphasis on the types of planters that they use.
ii. Let farmers practice at selecting the correct seed plate or seed hole for the type of seed provided.
iii. Have the farmers pull the planter a few meters to demonstrate how the seed drops.
iv. Hitch the planters to the donkey teams and practice row planting.
v. Hitch the cultivators to the donkey teams and practice inter-row cultivation.

A discussion of the following theoretical aspects could be included in the training program:

i. Seedbed preparation.
ii. Seed and seeding.
iii. Types of yokes.
iv. Importance of row planting.

13.3.3 ORGANIZATIONS WHICH MAY OFFER ASSISTANCE IN TRAINING, AND THEIR ROLES

(a). ***Trusts, Brigades And Other NGOs.*** These non-governmental organizations have played an important role in farmer training. For example, the Palapye Development Trust (PDT) assists in the training process by providing training facilities (e.g., equipment, traction animals, etc.) and has personnel who can carry out the training.

(b). ***Rural Training Centers.*** Provide trainers and logistical support. The Mahalapye RTC has done this on many an occasion.

(c). ***Department Of Agricultural Research.*** Provides trainers and logistical support. The workshops offered by this department provide an opportunity to explain to the farmers the findings from research conducted.

(d). ***Extension Service.*** Selection of farmers, sites, and general organization of farmer training workshops.

(e). ***ALDEP.*** Trainers and training equipment are provided by this organization.

13.3.4 IMPACT ASSESSMENT

An impact assessment involves undertaking a follow-up of farmers' activities during the season. It provides feedback on the effectiveness of the training, and also identifies problem areas that need to be included in future training courses. This assessment can be undertaken by any of the people involved in the training since they all, at one point or another, need to visit the farmers. To date, ATIP has taken the lead in carrying out these follow-ups. Assessments were made on the farmer's ability to row plant, and to identify any problems that were encountered. Issues that relate to yield were measured.

13.4 PARTICIPATION IN AGRICULTURAL SHOWS

13.4.1 BACKGROUND

The participation of research personnel in District Agricultural Shows provides an ideal opportunity for interaction between farmers and researchers. This interaction allows the farmers a chance to see what new technologies have been developed, and for researchers to obtain feedback on such technologies.

At times researchers work with other groups in organizing these agricultural shows. For example, ATIP and extension personnel in Mahalapye successfully co-sponsored row planting contests at agricultural shows during the 1987-88 and 1988-89 seasons. While it is not possible to cover all aspects of organizing a variety of agricultural shows, the following discussion of the row planting competitions illustrates, in general, what is involved and identifies points to consider when undertaking such an activity.[3]

The purpose of such contests is to promote quality row planting and at the same time entertain the audience while conveying a message. Potentially such contests could be held not only at the district but also at the national level. Those farmers who were the best row

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[3]. See Modiakgotla, Siebert, Makhwaje and Dira [1990] for a more detailed discussion.

planters in their respective districts could be given the opportunity to compete for the National Row Planting Championship title. Such a competition could be run on a yearly basis.

13.4.2 ORGANIZING THE CONTEST

Organizing a farmer contest is not difficult if the relevant agencies of the Ministry of Agriculture collaborate. Each agency has a very important role to play. Ideally, a working committee should be formed to handle the details of the contest.

The working committee should represent all the agencies that have a common message to convey to the audience, and its selection should be done well in advance to allow enough time to organize the activity. In the past, a number of agencies have been represented, including the DAO, RTC, ALDEP, APRU, Agricultural Information Division of DAFS, ATIP, etc.

The working committee allocates tasks according to the mandates of each participating agency. For example:

(a). The DAO's office and the ADs can publicize the event at the village level thereby attracting potential contestants and spectators. A list of participants is drawn up and presented to the working committee. Each participant is to be briefed on all aspects of the contest, and what is expected of them. Additionally, it is important to ensure that the contestants have the necessary equipment, animals and personnel in order to be able to participate.

(b). The Rural Training Center (RTC) can provide food for all contestants. Where contests are held near a Rural Training Center, such a center could be used as a source of accommodation for contestants. For other areas, it may be advisable for the district extension office to organize the accommodation. The RTC may also be assigned the responsibility of holding a rehearsal with the participants. At the rehearsal it is important make sure that farmers know how to select the correct seed plate [DAR, No Date] and adjust their planters, explain the depth of seed placement in relation to soil moisture, explain the rules and regulations of the contest, etc.

(c). ALDEP have, in the past, provided prizes for the contests. Since they are so heavily involved in providing animal traction and equipment to farmers, it is likely they will also take major responsibility for organizing contests in future years.

(d). The Animal Production Research Unit (APRU) in DAR, can sometimes provide transportation of traction animals since they are used to undertaking such operations.

(e). The Agricultural Information Section of DAFS can be invited by the working committee to help provide commentary, and keep the contest interesting for the spectators.

(e). Farming systems teams can provide a supportive or back-up role. Until now, ATIP has played a leading role in the general organization of the contests in the Central Agricultural Region. However, in the future, as indicated above, it is planned that major responsibility will handed over to ALDEP and other extension personnel within the regions.

13.4.3 CONTEST REQUIREMENTS

There are a number of actions that need to be undertaken in order to ensure the contest is successful. A few of them are as follows:

(a). The plots have to be prepared. Each contestant requires plot of 10m x 30m is enough for one contesting team. The plot must be plowed in advance and levelled, if necessary. Plot boundaries need to be marked with lime and the distance between boundaries should be more than two meters. A barrier needs to be built around the contest area in order to distance the audience from the contesting teams. Enough room needs to be left at the headlands for easy turning of animals.

(b). Banners can be used to indicate who the participating agencies are, while posters can provide the audience with information related to the contest activity.

(c). Flags of steel wire of about 50cm lengths with a small peace of plastic stapled at one end can then be used in each row to represent plants, and are placed at about 50 centimeter intervals. Crop stover can be used instead of flags.

(d). **Kraals**, animal feed and water need to be made available for the animals of the contestants.

(e). Judges need to be selected and agreement needs to be reached on the scoring system to be used. Judges may include extension and other knowledgeable personnel such as farmers experienced in row planting. It has been found that for most contests a total of six judges is about optimal, but of course this will partly depend on the number of teams contesting. Table 13.1 provides an example of a possible scoring system to be used in the judging contest.

TABLE 13.1: SUGGESTED SCORING SYSTEM FOR ROW PLANTING CONTESTS

TASK	POINTS POSSIBLE	POINTS OBTAINED
Seed plate setting	0-10	_____
Correct hitching	0-10	_____
Speed of row planting	10	_____
Quality of row spacing	0-10	_____
Straightness of rows	0-10	_____
Seed placement	0-10	_____
Inter-row cultivation speed	10	_____
Quality of inter-row cultivation	0-10	_____
Handling of donkeys	0-10	_____
General knowledge on row planting	0-10	_____
TOTAL POINTS		_____

(f). In order to provide good quality commentary, script preparations need to be undertaken well in advance. The commentator needs to be able to explain how the farmers were selected, to convey personal information about the contestants, what the farmers are expected to provide, what the contestants will be expected to do, how judges will evaluate the contestants, etc. This information needs to be reported at several points during the contest itself, along with a running commentary on the actual activities taking place, etc.

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Section 13.3:

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Section 13.4:

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APPENDICES:

A: REFERENCES

B: GLOSSARY

C: ACRONYMS

D: FORMS IN ANNEX VOLUME

APPENDIX A: REFERENCES

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APPENDIX B: GLOSSARY

Substantial lists of definitions are found in other publications. Particularly useful ones are found in Amir and Knipsheer [1989], Byerlee et al., [1980], Caldwell, Taylor and Walecka [1987], and Shaner et al., [1982]. Some of the technical terms used in the handbook are defined on the following pages. Other common technical terms not mentioned in the handbook which readers will often see in other FSR literature are also given. The following list of definitions is taken mainly from the references just cited.

Acceptability Index: The percent of representative farmers using a technology times the percent of the crop land for which the technology is used, divided by 100. This gives an index with a range from 0 to 100.

Agro-Climatic Zones: Zones, areas or environments with similar agro-climatic conditions but not necessarily adjoining each other. Where a crop exhibits roughly the same biological expression, so that, for example, a similar variety of fertility responses would be obtained within a given environment, everything else being equal.

Agro-Economic Zones: Zones that are defined in terms of common features; may involve such dimensions as climate, soil resources, land use, ethnic grouping, and market access.

Alternative Hypothesis (Ha): The alternative to the null hypothesis. Expresses the idea of difference or significance of difference, in contrast to the null hypothesis.

Analysis of Covariance: An extension of analysis of variance in which the treatment means of the variable of interest are adjusted to values they would have if there were no variation in the values of a second variable, called the covariate.

Analysis of Variance (ANOVA): A statistical method for comparing variance in responses among treatments with variance reflecting natural variation in fields, and assessing the probability that the differences among treatments are due to the effects of the treatments themselves, rather than to natural variation.

Baseline Data: Data collected at the beginning of a project/study (e.g., on crop yield, labor input, market prices, etc.), against which later results can be evaluated.

Benefit-Cost Ratio: A ratio of discounted returns to discounted costs.

Binomial: A type of data format used in questionnaires which restrict responses to a "true" or "not true" answer, i.e. "1" or "0" entry.

Block: A group of plots similar in certain characteristics (e.g., soil type, fertility, plant stand, etc.) prior to the application of the treatments.

Budget: The sum of all expected products (or increased inventories) times their respective prices, less the costs of all items used in production.

Budgeting: Budgeting is a type of economic analysis based on costs and returns of production.

By-Products: Materials produced as wastes in some industrial or food-preparation process that may be used as feed.

Capital Intensive: An enterprise in which capital inputs make up the largest proportion of total inputs. Usually, capital intensity is measured against the levels of labor and/or land used in the enterprise. In most cases, the relative level of capital must equal or exceed an arbitrary relative level selected for the study.

Capital: Wealth in any form, such as money or property, that can be used to produce more wealth.

Ceteris Paribus: All other things being equal.

Character: In computing work, a type of data format which contains alphabetical and numeric entries.

Choices: The options available to the decision maker.

Choice Criterion: A measure adopted as a basis for comparing the consequences of alternative acts.

Cluster Sampling: A form of multistage sampling in which all the units at the last stage are sampled.

Coefficient of Determination (R^2): A statistic measuring the proportion of the variation in a set of data which is associated with the least-squares regression equation describing the data.

Coefficient of Variation: A statistic used to measure relative variability; the ratio of the standard deviation to the mean, expressed as a percentage.

Commodity-Oriented Research: The focusing of research on one or more crops or animals by studying them in detail. Commodities are usually selected on the basis of investigations that have demonstrated their importance to the farming system.

Complementary Relationships: Refers to relationships within the farming system which are formed to be mutually beneficial for each party involved (e.g., draft animals help in the cultivation of crops, while crop residues are food for livestock).

Complete Blocks: Every block has all treatments in the experiment, so the number of replications equals the number of blocks.

Completely Randomized Design (CRD): The research team randomizes treatment over all plots, and there are no blocks.

Confidence Interval: The population mean U_x is somewhere between the mean of a sample of $X \pm zS_x$. This interval is called a confidence interval for U_x. The zS_x is some multiple of the standard deviation of the sampling distribution X.

Continuous Data: Data on which the data points can be any value and any number of intermediate values are possible (e.g., yield in kg/plot: between the value 1 kg/ha and the value 2 kg/ha, intermediate values such as 1.25, 1.5, etc., kg/ha are possible).

Correlation Coefficient (r): A measure of the degree of association between two variables. It does not indicate direction of cause-and-effect.

Covariance Analysis: See ***Analysis of Covariance***.

Criteria: Principles or standards by which something is judged.

Cropping Pattern: The arrangement of crops on a given field over a given period of time (usually 12 months).

Cropping System: The crop production activity of a farm. It comprises all components required for the production of the set of crops of a farm and the relationship between them and the environment. These components include all necessary physical and biological factors, as well as technology, labor, and management.

Cropping Systems Research: Such research concentrates on crops and cropping patterns, alternative management practices in different environments, and interactions between crops, between crops and other enterprises, and between the household and environmental factors beyond the household's control. The procedures are similar to farming systems research, but the breadth is generally less.

Database: An organized file of information on a particular study or subject which is maintained in a data storage system such as a computer file.

Degrees of Freedom (DF): The number of comparisons possible. It is always one less than the number of blocks, treatments, plots, etc., the divisors for each sum of squares in an analysis of variance. It is the number of observations in the data collection that are free to vary after the sample statistics have been calculated.

Discipline: Refers to a particular field or study, e.g., agronomy, agricultural economics, etc.

Discrete Data: Data in which the data points are whole numbers, and intermediate values are not possible (e.g., number of pods on a sample plant: between the value 1 pod and the value 2 pods, there cannot be intermediate values such as 1.25, 1.5 etc., pods)

Domain: A group of sampling units amongst which there is a high degree of homogeneity.

Downstream FSR Programs: FSR programs that identify and test possible innovations that easily integrate into existing farming systems by focusing on close interaction with farmers via on-farm trials; also known as site-specific FSR programs. Is somewhat analogous to "FSR with a pre-determined focus" and "FSR in the small".

Dryland: Land that, except for limited periods, does not hold moisture in the rooting zone in excess of that held at field capacity.

Economic (Societal) Analysis: Analysis of projected benefits and costs from the viewpoint of the economy or society.

Economic Feasibility: Activities and investments that produce benefits in excess of costs when the time value of money is considered.

Endogenous Factors: Those factors under the control of the farmer.

Enterprise: Activity undertaken to produce an output that contributes to total production or income of the farm family. Enterprises in FSR typically concern crops, livestock, processing, or upgrading agricultural commodities produced on the farm; productive non-agricultural activities carried out on the farm (such as handicrafts), and productive off-farm activities carried out by the household members.

Enterprise Budget: A projection of costs and returns for a specific farm enterprise identified by unit of production and time period of production.

Environment: Consists of the technical (natural) and human (socio-economic) environments. Physical and biological factors constitute the natural element or environment while the human element can be divided into endogenous and exogenous factors.

Ex Ante Analysis (Evaluation): Analysis done before the event of the expected biological, economic and/or social benefits of trial and/or treatment choices prior to conducting the trials, in order to make decisions about trial type and treatments.

Ex Post Analysis (Evaluation): Analysis performed after the event (looks at what actually happened). The analysis examines the effects/impact from introducing new farming systems technologies and may be concerned with the following: adoption rates, profitability, enabling and constraining factors.

Exogenous Factors: Factors outside the control of the individual farmer (e.g., general availability of fertilizer)..

Experimental Design: How to arrange treatments in fields and among farms so that researchers can analyze the differences in responses among treatments using statistical methods.

Experimental Error: The error in an experiment that leads to differing responses resulting from the same experimental treatment.

Experimental Variables: Those variables in an experiment that the researcher tests (e.g., fertilizer,

varieties of seed, etc.)..

Exploratory Survey: A process by which the researchers move through the target regions and informally interview farmers and other persons knowledgeable of agriculture to arrive at a tentative understanding of farmers' existing production technologies and constraints to farmers' production and income.

Extension: Those agencies whose role involves the diffusion of agricultural information.

Factor: In statistics is a group of related treatments.

Factorial: Refers to the manner in which treatments are assembled. A complete factorial experiment includes all possible combinations of the selected levels in two or more factors. Analysis of variance includes interaction term(s).

Farm: An organized decision making unit within which crop and livestock production, together with off-farm activities, are carried out for the purpose of satisfying the farming family's goals.

Farm Management: A science that deals with the proper combination and operation of production factors (including land, labor, and capital) and the choice of crop and livestock enterprises to bring about a maximum and continuous return to the most elementary operation units of farming. It concerns the sound organization and skillful operation of a farm business for the purpose of maximizing continuous benefits consistent with the objectives of the farm operator or farm household.

Farmer Feedback: The assessment by the farmer of a technology or methodology being tested or demonstrated by extension or research.

Farmer-Managed Trial: On-farm experiment managed by the farmer to learn how farmers implement suggested improvements.

Farming Enterprises: Production activities on a farm (e.g., crop production or animal production).

Farming Systems Research (FSR): An approach to agricultural research and development that: (a) views the whole farm as a system, (b) focuses on the interdependencies among the components under the control of members of the farm household, and how these components interact with the physical, biological, and socio-economic factors not under the household's control, and (c) aims at enhancing the efficiency of farming systems by improving the focus of agricultural research in order to generate and test better technology. FSR focuses primarily on the technology component.

Farming Systems Work (FSW): Unlike FSR, it incorporates an interest in improving policy/support systems as well as in technology development.

Farming System: A unique and reasonably stable arrangement of farming enterprises (i.e., crops, livestock and off-farm) that a household manages according to well-defined practices in response to the physical, biological, and socio-economic environments, and in accordance with the household's goals, preferences, and resources. These factors combine to influence output and production methods.

Field Book: A field book is a set of data collection forms on which to record all of the data to be collected in the field for a particular trial.

Field Cost (Of An Input): The field price of an input multiplied by the quantity of an input used.

Field Price (Of An Input): The value which must be given up to bring an extra unit of input into the field. Can be either the money field price or opportunity field price.

Field Price (Of An Output): Is the value to the farmer of an additional unit of production in the field. Depending on the end use of the product, it can be valued as either the money field price or the opportunity field price.

Field (Farming Systems) Team: A group works with farmers on their fields. Such teams often consist of agronomists, economists, and supporting technicians. Where livestock is important, an animal

scientist should be part of the team; and in areas where women are responsible for growing important crops or performing critical operations, field teams should include women.

Field: In computing work, it is an individual item of data within a record, such as a farmer's name.

File Name: The identifier used for a set of data stored on a computer disk. For IBM computers the file name can be up to eight characters or numbers followed by a period and three additional characters or numbers.

Financial Analysis: Analysis of benefits and costs from the viewpoint of the economy or individual.

Fixed Cost: A cost remains constant with the varying levels of output.

Formal Survey: A survey of randomly chosen farmers who are interviewed by trained personnel using a written questionnaire to provide quantitative data on a farmer's circumstances.

Frequency Distribution: A table or graph indicating the frequency of occurrence of particular values of a variable.

F-Test (F-Ratio): The ratio of one variance (or mean square) to the error variance (or mean square); this ratio is compared with tabulated ratios to determine significance. Also called the variance ratio.

Heart (Chest) Girth: The distance around the chest just behind the front leg.

Heterogenous: Many different types (e.g., would be those farmers who farm under dissimilar conditions and in diverse ways).

Homogeneous: All of a similar type (e.g., would be those who farm under similar conditions and in similar ways).

Household Goals: Aspirations the farm family has, such as increased income, adequate education, and improved quality of life, and which may vary from one family to another.

Household: The farmer and other members of the family who form a consuming and producing unit and a social organization. Households are often under the management of a single person, but sometimes operate collectively. Members normally live and sleep in the same place, share meals, and divide household duties. Household members share some goals, benefits and resources. They are independent on some and in conflict on others.

Hypothesis: A tentative statement or explanation of certain observed facts that is used as a basis for further investigation or argument.

Hypothetical: Relating to a situation or set of circumstances which does/do not exist in the real world, and is used only as an example of what could possibly exist.

Informal Survey: Surveys undertaken without formal sampling procedures, pretested questionnaires, and other means that permit statistical analysis. The interview is sometimes structured according to a checklist of information but with flexibility to explore certain practices or problems in more depth depending on the farmers' responses. See also ***Rapid Rural Appraisal***.

Infrastructure: The supportive features of an economy often provided by government but sometimes provided by private industry, e.g., transportation, electricity, water, communication, and governmental organizations.

Input: A factor of production, i.e., land, labor and capital.

Intercropping: Growing two or more crops simultaneously in alternating rows or sets of rows in the same plot (see also Mixed Intercropping).

Interdisciplinary: A term describing frequent interactions among those from different disciplines who work on common tasks. Interdisciplinary activities tend to have better results than if those

involved had worked independently.

Inter-Household: Refers to interactions and relationships between two or more households and their members.

Intra-Household: Refers to interactions and relationships among members of the same household.

Internal Rate Of Return: A rate of interest at which the net present value of an investment is zero.

Iterative Process: An approach that involves repeating activities and calculations to arrive at improved solutions through a series of successively better approximations.

Interview Guidelines: These guidelines provide advice on various aspects of the interviewing process. For example, the guidelines may include a list of topics/issues which are to be covered in the interview, or they may advise on how to conduct an interview (e.g., length of the interview).

Key Informant: A knowledgeable person such as a local government official, leader, extension or development staff member who has good background information relating to the objectives and the area to be studied.

Law Of Diminishing Marginal Returns: As equal increments of a variable input are combined with other fixed inputs in a production process, there will come a point where additions to total revenue (i.e., marginal revenue) will decline.

Least Significant Difference (LSD): The smallest difference between any two means that can be accepted as statistically significant.

Least-Squares Regression: See ***Regression Analysis.***

Linear Programming: is a mathematical technique used in farm planning which involves choices between a number of options subject to resource and other constraints.

Linear Regression: See ***Regression Analysis.***

Livestock Systems: Sub-systems within the farming system made up of a set of one or more animals and comprising all components required for their production, including the interactions among the animals, other household enterprises, and the physical, biological, and socio-economic environments.

Management Factors: Those factors the farmer can control through management decisions including such variables as; cropping and livestock patterns, crop varieties, field cultural practices, fertilization, pest control, irrigation management, harvest data, sale of crop of animal products, use of labor, animal, or mechanical power, and post-harvest losses.

Management Level: The level of non-varying or basal factors applied uniformly to an experiment.

Management Practice: The use of a technological component defined by the type, amount, and timing of the component.

Marketing: The performance of activities that will result in moving commodities from the producer to the consumer.

Mean: The mean, or the sample mean (also called the mean of the sample) is the arithmetic average of a given sample. The mean is calculated by dividing the sum of the observations by the number of observations.

Measurement Error: This relates to mistakes made in the enumeration and analysis of the data, e.g., faulty recording of responses, etc. Such errors occur in any type of data collection and are due to organizational and administrative deficiencies. Unlike sampling errors, this type of error is not randomly distributed. Measurement errors also tend to increase as the number of respondents becomes larger.

Minimum Data Set: A minimum data set is a listing of all variables which will have data collected on them during a given trial, survey or study. This data set is the minimum amount of data which must be collected to complete the objectives of the trial.

Mixed Intercropping: Growing two or more crops simultaneously, intermingled in the same plot with no distinct row arrangement.

Modified Stability Analysis: A type of regression analysis in which several individual treatments, at each location, are used as the values of an independent variable called the environmental index.

Money Field Price (Input): Refers to the purchase price plus other direct expenses such as transportation costs.

Money Field Price (Output): Refers to the market price of a unit of product minus storage, transportation and marketing costs.

Multidisciplinary: Involves scientists from several disciplines, but the effort is planned, executed and evaluated by each person separately.

Non-Experimental Variables: Those variables not tested by the researcher in an experiment. They are divided into those that the researcher cannot control, such as weather, and those that they can control, such as farming operations. In FSR work, the team generally tries to hold the latter at the farmers' level, but sometimes may use the level recommended by the extension service.

Non-Random Sampling: Method of sampling in which individuals are chosen by purposely selected units without the use of a population list. See also ***Purposive Selection***.

Null Hypothesis (Ho): The working hypothesis which expresses the idea of no difference or of non-significance of difference.

Opportunity Cost: The value of an input or output in its best alternative use.

Output: The product (e.g., sorghum).

Parameter: If records were collected for the entire population of the universe (all the farms in the country) as in a census, only one fixed value could be obtained for each of these measures. These true fixed values for the entire universe are designated parameters.

Partial Budget: A form of analysis designed to show net income change resulting from a move from one technology to another. It will not show profit or loss for the farm as a whole. Thus it is a method of economic analysis which compares changes in variable costs and returns to assess the economic benefit of treatment differences.

Partial: A term used to indicate that the change only occurs in one component of the farm.

Plant Population: Numbers of plants per hectare -- or other measure of land area. Plant populations can be controlled by seeding rates and/or plant thinning to reduce population.

Plot: An adjoining area of land planted in a homogeneous manner during a defined period, normally a year. Thus it is a name given to the physical location of each treatment or treatment combination in a given trial.

Policy: Refers to actions and rules of governments implemented in order to meet regional or national development goals.

Potential Leverage: Is maximized where adoption of a change can have the greatest positive impact on the productivity of the farming system.

Primary Data (Information): Data directly collected by the FSR team.

Private Goals: Refers to ambitions/desires/needs that the farming family wants to achieve (e.g., to grow enough food to be self-sufficient).

Probability: The chance of an occurrence.

Probability Distribution: The spread of observed values around an actual value.

Productivity: The amount of output per unit of input.

Purposive Selection: A sample chosen to ensure that participants with certain characteristics are included. For example, choosing a sample to ensure that male and female-headed households are represented in the same proportion as they are found in the total population.

Random Sample: A sample drawn so that every unit in the population or sub-population has an equal probability of being selected.

Randomized Complete Block Design (RCBD): The research team randomizes treatments within blocks.

Rapid Rural Appraisal: This term refers to those techniques that attempt to optimize cost-effectiveness with an emphasis on timely reporting and low demands on staff. This method attempts to produce fairly quick, relatively clean research and recommendations. The techniques combine types of information and methods of investigation such as informal surveys, interviews using checklists rather than questionnaires, group interviews, and other ways of working with and learning from farmers.

Recommendation (Crop Production): Advice in terms of operations, times, equipment, and materials for crop production, presented as worthy of acceptance. Is information that farmers can use to improve the productivity of their resources (farming system).

Recommendation Domain. A recommendation domain is a group of roughly homogeneous farmers with similar circumstances for whom the same recommendation can be made. Recommendation domains may be defined in terms of natural factors (e.g, rainfall) and/or socio-economic factors (e.g., area cultivated, traction type, etc.).

Reconnaissance Survey: See ***Rapid Rural Appraisal.***

Record: In computing work, is information on an individual person or case within a database.

Regression Analysis: Is a statistical method for fitting continuous functions involving a single dependent and one or more independent variables. Linear regression involves relating a dependent variable to one independent variable. Graphically, the relationship is a straight line.

Replication: The repeating of treatments in more than one plot.

Researcher-Managed trials: On-farm experiments managed by researchers to develop and/or test new technologies under conditions approximating that of the farmer.

Residual Error: A statistical measure of random variability not accounted for by treatments, blocks, or other sources of variation imposed or accounted for by researchers.

Resource Endowments: The amount and quality of resources (in the forms of land, labor, capital, etc.) available in a particular region or to a particular group of farms or to an individual farm.

Resources: The means available for producing goods that are used to satisfy human wants. Land, labor and capital are common resources.

Risk: The chance of some favorable or unfavorable event occurring. Occurrences that can be quantified on the basis of probability analysis.

Sample: A number of individual units selected from all those units that compose a particular population.

Sample Survey: Used to identify the many farm settings in which inferences about the larger population are desired.

Sampling: The process or technique of choosing the sample.

Sampling Error: This relates to the fact that a sample, chosen from a population, does not perfectly represent the population. This type of error is expected to be randomly distributed. It is a measure of how close the statistics from the sample represent the larger population. It consists of two elements: the Confidence Level and the Confidence Interval.

Sampling Frame: A list of the members of a population from whom a sample is to be drawn.

Sampling Unit: The object of observation measurement, or data collection. Examples include pods on a plant, plants in a field, rows in a field, plots in a field, fields in a domain, farm households in a domain, etc.

Scatter Diagram: A figure drawn on two axes representing two variables with paired values of the two variables plotted to show the distribution of observations.

Secondary Data (Information): Data that were collected and documented by someone else.

Sensitivity Analysis: Partial budgeting done using input and/or product prices different from those actually observed during the experiment, but which have occurred in the past or could be expected to occur at given probabilities in the future.

Setting Priorities: Assigning priorities to research topics means to rank them by order of importance. The most important item would be ranked highest priority, the second most important item would be the second priority, and so on

Significance Levels: The probability that an observed difference will be declared to be due to the treatments when it is actually due to random variation, expressed as a percentage. The percentage -- 100 minus the significance level -- is the probability that the observed difference is due to the treatments.

Societal Goals: Refers to the ambitions/desires/needs of the community/society to which the farming family belongs (e.g., the community would want the farming families to grow enough food so that the community can have a good and reliable source of food).

Sole cropping: The growing of only one crop at a time on a plot of land.

Sondeo: See ***Rapid Rural Appraisal Survey***.

Standard Deviation: A measure of the absolute variability among experimental units of measurements and/or plot sizes. Is the square root of the variance.

Statistics: A branch of mathematics dealing with the collection and interpretation of sets of data according to well-defined procedures.

Stratification: A process of dividing a population into homogeneous sub-groups to increase sampling efficiency. Stratification follows as closely as possible the definition of recommendation domains.

Stratified Random Sampling: Sampling in which the underlying population is divided into two or more strata, and random sampling is done independently within each stratum. The strata are analogous to blocks in field experiments.

Superimposed Trials: Treatments added to fields already planted by farmers.

Supplementary Relationships: Refers to relationships within the farming system which are are completely independent of each other (e.g., keeping chicken on free range has no negative or positive impact on growing crops).

Support Services: Systems that will determine the appropriateness of a new technology - e.g., roads, transportation, markets, available credit, irrigation, and sources of supply for equipment, seed, herbicides and fertilizer.

System: Any set of elements or components that are interrelated and interact among themselves. Specification of a system implies a boundary delimiting the system from its environment. Two systems may share common components of an environment, and one system may be a sub-system of another.

T-Test: A method for comparing two means. It is often the second step following an analysis of variance.

Target Area: A geographical area or specific type of environment that a FSR team is expected to address.

Technical Feasibility: The potential of a new technology to result in higher yielding animals or crops.

Technology: The combination of all the management practices used for producing and otherwise managing a given crop, crop mixture, livestock, or other farm activity.

Test: Statistical test used to estimate the reliability of an experiment by determining how consistently the experiment will measure a given parameter.

Transformations: A mathematical operation, e.g., taking the square root, that is applied uniformly to every value in a data set, in order to convert the data set to a modified data set with properties (such as equality of variances of treatment means) that better fit the assumptions that must be met to use statistical analysis of treatment differences.

Treatment: What researchers do to one area of the crop or animal, in order to compare with other areas to which they do something different or nothing at all. Treatments can include interventions, researcher controls, average farmer controls, and individual farmer controls.

Two-Stage Sampling: A sampling procedure in which sub-populations such as villages are selected first, then units such as farmer groups are chosen within each selected sub-population.

Type I Error: The error that is committed when a null hypothesis is rejected when it is true, and an alternative hypothesis is accepted which is false.

Type II Error: The error that is committed when a null hypothesis is accepted but false, and the rejected alternative hypothesis is actually true.

Unit Of Analysis: The basic unit under study in a particular situation. For example, this may be a farm family, a hectare growing a particular crop with a specified technology, or a cow-calf unit.

Upstream FSR Programs: FSR programs that generate prototype solutions leading to major shifts in the potential productivity of farming systems in general. In essence, this is "FSR in the large."

Variability: Differences in responses of treatments. May be partitioned (by correct experimental design) into one or more of the following: treatment, block (replication) and interaction error.

Variable (Factor): An experimental treatment, or a component of an experimental treatment.

Variable Costs: Costs that vary with the level of input.

Variable Input: An input in a production process, the level of which is variable. Often the level used can be chosen by the decision maker.

Variance: A mathematical measure of variability estimated as the mean square. It is the square of the standard deviation.

Whole Farm Analysis: A methodology designed to search for optimal solutions through incorporation of farmers' objectives, farming systems, and resources to arrive at improved cropping and livestock patterns and management practices for overall farming systems performance.

Whole Farm Budget: A budget drawn up to show the anticipated consequences, in terms of selected measures of performance, of some actual or proposed farm plan.

APPENDIX C: ACRONYMS

AD	Agricultural Demonstrator
ADNP	Agricultural Development for Ngamiland Project
ALDEP	Arable Lands Development Programme
ANDP	Agricultural Ngamiland Development Project
ANOVA	Analysis of Variance
APRU	Animal Production Research Unit
ARAP	Accelerated Rainfall Arable Program
ATIP	Agricultural Technology Improvement Project
BAMB	Botswana Agricultural Marketing Board
CATIE	Tropical Agricultural Research and Training Center
CIMMYT	International Maize and Wheat Improvement Center
cm	Centimeter
CPDF	Cumulative Probability Density Function
CRD	Completely Randomized Design
CTO	Central Transportation Organization
CV	Coefficient of Variation
DAFS	Department of Agricultural Field Services
DAO	District Agricultural Officer
DAR	Department of Agricultural Research
DLFRS	Dryland Farming Research Scheme
DM	Dry Matter
DPS	Division of Planning and Statistics
DPSM	Directorate of Public Service Management
DR	Drought Relief
EFSAIP	Evaluation of Farming Systems and Agricultural Implements Project
FAO	Food and Agriculture Organization
FMFI	Farmer Managed, Farmer Implemented
FS	Farming Systems
FSAR	Farming Systems Approach to Research
FSR	Farming Systems Research
FSR & D	Farming Systems Research and Development
FSR/E	Farming Systems Research/Extension
FSSP	Farming Systems Support Project
FSSR	Farming Systems Southern Region
FSW	Farming Systems Work
GOB	Government of Botswana
ha	Hectare
IFPP	The Integrated Farming Pilot Project
IRRI	International Rice Research Institute
kg	Kilogram
km	Kilometer
LAC	Livestock Advisory Center
LSD	Least Significant Difference
m	Meter
MC	Marginal Costs
MDP	Molapo Development Project

ml	Milliliter
mm	Millimeter
MOA	Ministry of Agriculture
MPP	Marginal Physical Products
MR	Marginal Returns
MRA	Marginal Returns Analysis
MVRU	Multiple Visit Resource Unit (survey)
NCS	National Conservation Strategy
NGO	Non-Governmental Organizations
NNB	Net Nutritional Benefit
OFR	On-Farm Research
OFR/FSP	On-Farm Research with a Farming Systems Perspective
OSR	On-Station Research
PDT	Palapye Development Trust
RAVC	Returns Above Variable Costs
RCBD	The Randomized Complete Block Design
RDA	Recommended Dietary Allowance
RELO	Research Extension Liaison Office
RIIC	Rural Industries Innovation Center
RMFI	Researcher Managed, Farmer Implemented
RMRI	Researcher Managed, Researcher Implemented
RSU	Rural Sociology Unit
RTC	Rural Training Center
TCR	Technical Component Research
TLGP	Tribal Land Grazing Land Policy
USAID	United States Agency for International Development
VMP	Value of Marginal Physical Products

APPENDIX D: FORMS IN ANNEX VOLUME

Examples of many forms used in ATIP's work over the years are included in the Annex Volume [Worman, Norman and Ware-Snyder, 1990]. A list of those included is given below.

SECTION A1: VILLAGE AND FARMER SELECTION SURVEYS
- A1.1 EXPLORATORY SURVEY
- A1.2 CENSUS FRAME SURVEY OF ARABLE AND LIVESTOCK FARMING PRACTICES

SECTION A2: MULTIPLE VISIT SURVEYS
- A2.1 MULTIPLE VISIT RESOURCE UNIT SURVEY -- HOUSEHOLD PROFILE
- A2.2 MULTIPLE VISIT RESOURCE UNIT SURVEY (MVRU)

SECTION A3: BASELINE SURVEYS
- A3.1 BASELINE SURVEY FORM, TUTUME AGRICULTURAL DISTRICT
- A3.2 TRADER BASELINE SURVEY
- A3.3 1989 BEAN BASELINE SURVEY
- A3.4 BASELINE SURVEY FOR FARMER GROUPS

SECTION A4: FIELD TRIAL RECORD SHEETS AND END-OF-SEASON SURVEYS
- A4.1 FIELD BOOK FOR RMRI AND RMFI TRIALS
- A4.2 FIELD BOOK SHEETS FOR MAHALAPYE TRIALS
- A4.3 FARMER GROUPS TECHNOLOGY OPTIONS TESTING
- A4.4 1989 END-OF-SEASON TRIALS ASSESSMENT SURVEY FOR RESEARCHER LED OPTION TESTING GROUPS

SECTION A5: PRICE AND MARKETING SURVEYS
- A5.1 ATIP PRICE SURVEY GROUP/TRADER FORM
- A5.2 RESOURCE VALUATION SURVEY
- A5.3 LIVESTOCK PURCHASES

SECTION A6: LIVESTOCK TRIAL FORMS AND SURVEYS
- A6.1 COOPERATOR MILKING RECORD
- A6.2 WEEKLY DATA SHEET -- RESEARCH AND DEMONSTRATION KRAAL
- A6.3 LIVESTOCK INVENTORY SURVEY
- A6.4 LIVESTOCK INVENTORY CHANGES
- A6.5 ATIP MAHALAPYE LIVESTOCK PRACTICES SURVEY

SECTION A7: SPECIAL PURPOSE SURVEYS
- A7.1 ATIP AGRICULTURAL DEMONSTRATOR SURVEY
- A7.2 COOPERATOR ASSESSMENT SURVEY 1988-89
- A7.3 HORTICULTURE PRODUCTION SURVEY
- A7.4 FARM FIXED CAPITAL INVENTORY
- A7.5 1989 DONKEY HARNESS SURVEY
- A7.6 SURVEY FOR THE ROTARY INJECTION PLANTER
- A7.7 ATIP CART SURVEY
- A7.8 ATIP TRACTOR OWNER SURVEY
- A7.9 ARAP AND DROUGHT RELIEF SURVEY FORM USED BY ATIP
- A7.10 MATHANGWANE INFRASTRUCTURE, SERVICES AND INDUSTRY
- A7.11 ROW PLANTING FIELD COURSE IMPACT ASSESSMENT
- A7.12 ROW PLANTER CONDITION SURVEY