FARMING SYSTEMS RESEARCH AND EXTENSION IN HARSH ENVIRONMENTS: DEVELOPMENT OF A FARMER COOPERATOR APPROACH IN BOTSWANA

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INTRODUCTION

On-farm research programs following a farming systems (FS) approach have proliferated rapidly during the past five to ten years. Most ministries of agriculture of low income countries have one or more FS projects and many have begun to institutionalize national FS programs. This is true, for example, in southern Africa, largely as a result of an active CIMMYT training program under the leadership of Michael Collinson. As in southern Africa, international centers such as CIMMYT, ICRISAT and IRRI have played leading roles in developing and teaching FS work methods.

The rapid growth of the FS approach can be traced to many causes, including:

(a) Dissatisfaction with returns to investments in traditional agricultural research programs;
(b) Increasing concern with food production shortfalls and national food security;
(c) Inflated expectations concerning green revolution changes through modest investments of research and extension resources in farm system diagnosis and on-farm trials; and
(d) Substantial subsidies of FS programs through bilateral aid and from international donor agencies.

Not surprisingly, more has often been asked asked of FSR&E in national programs than had been the case at the international centers (Norman and Baker, 1984). On-farm research in national programs often is expected to contribute to national planning and to achievement of food security and equity objectives, as well as to the standard FS objective of increasing farm resource productivity through technological changes.

Over the last two years, we have noted a growing skepticism among development specialists and donor agencies about the potential of the FS approach. USAID, for example, is planning to revamp their African program by concentrating agricultural research resources on a few major food commodities emphasizing countries already having substantial investments in agricultural research. One of the main rationales presented in the USAID plan is the need for strong commodity based research (Agency for International Development, 1985). It is inevitable therefore that USAID support for FS projects in Africa will decrease.

We are concerned that the FS approach may be abandoned prematurely after having, initially perhaps, been too enthusiastically embraced by donor agencies. It may be that FSR&E will eventually be shown to be too expensive, both financially and in terms of human resources, for low income countries. But it is too early to tell. At present, there is a need to make long term commitments to see how and if the FS approach can help ministries of agriculture deal with the problems they are facing.

One of the most encouraging signs that the FS approach could eventually have a significant impact on national research programs is the attention being given to developing country and institution specific methodologies for FSR&E. Relatively few national programs have accepted FS methodologies developed at the international centers as a package. Rather, these methodologies have served as an outline for initiating FSR&E.

In light of innovations in FS methodology which are undoubtedly taking place elsewhere, while concurrently subsidies for FS programs are likely to start declining, an important task before us is to identify commonalities in our experiences in order to make sure resources used for FS activities are used effectively and efficiently. The halcyon days for FSR&E are over.

In this paper, we discuss FS methodology for harsh environments. We begin by characterizing common features of farming systems in harsh environments and identifying implications for FS program goals, and for FS technology design and evaluation procedures. We believe that FSR&E in harsh environments requires more understanding of system dynamics than in more equable areas where self-sustaining recommendations can be more quickly identified.

We then shift our discussion to a brief overview of the approach to FS work being used by the Agricultural Technology Improvement Project (ATIP) in Botswana. ATIP has a dual mandate:

(a) To develop, test, and disseminate relevant improved technologies for limited resource farmers; and
(b) To improve the capacity of the government of Botswana to develop and disseminate technologies.

A major objective of ATIP has been to identify appropriate procedures for FSR&E in countries such as Botswana, where the environment and a lack of technology already on the shelf prevent substantial improvements in farming system productivity, at least in a short or medium term framework.

CHARACTERISTICS OF FS WORK IN HARSH ENVIRONMENTS

Several features might be taken into account in determining whether a production environment is "harsh". In the Philippines, for example, the Farming Systems Development Project-Eastern Visayas is mandated to develop improved technologies for upland areas where soils are poor and unstable. Farmers can only cultivate lands for a few seasons before returning it to fallow for several years. In the arid and semi-arid zones of West Africa, uncertain rainfall poses a major problem, as the well-known "Sahalian drought" demonstrated.

To generalize, we define "harsh environment" farming systems as ones where farm production and resource productivity are low and unstable and the technical environment prevents substantial and/or reliable improvements in productivity.

In Botswana, we face a combination of low and erratic rainfall coupled with poor soils. In eastern Botswana, where most agricultural production takes place, the long term rainfall average is between 450 and 500 mm per year, with large inter- and intra-annual variations, and no month when rainfall exceeds potential evapotranspiration. In years of average or better rainfall, yields for sorghum, the staple food grain, are around 200 kgs per ha. During drought years the situation is much worse. Many farmers do not even plant and those that do get little or nothing for their efforts. Meanwhile, cattle, which form the backbone of the rural economy, die faster than they can be sold or are sold at prices much below their levels in normal seasons.

The three years of ATIP's existence have coincided with bad rainfall years for arable agriculture. Thus, ATIP has been faced with a particularly harsh environment as far as technology design and testing work is concerned. The three seasons have brought home to ATIP personnel several observations regarding the nature of farming systems in harsh environments. These observations perhaps pertain to farming systems in less harsh environments but are, we believe, particularly important in harsh environments.

In this section we identify implications of harsh environments for: (a) FS program goals and management; and (b) FS technology design and evaluation procedures, based on our observations in Botswana. Obviously, our observations only represent hypotheses which need to be examined against the experiences of other FS programs operating in harsh environments.

FS PROGRAM GOALS AND MANAGEMENT

Our general observation and hypothesis is that FS programs in harsh environments are, and have to be, broadly focused, encompassing much more than the primary concern of FS work with increasing farm productivity through technological change. The notion of a broader focus can be broken into four components.

1. In many countries where there are harsh environments, there are also areas that are more equable. Consequently, harsh environment systems often are not targeted in order to make substantial contributions to national income or production (Norman, Baker and Siebert, 1984). Rather, employment, equity, and food security goals often are dominant. For example, in Botswana reducing reliance on food grain imports from South Africa and creating employment opportunities through increases in arable crop production are important national goals even though Botswana's comparative advantage is in livestock and mineral production. Thus, FS activities are not necessarily focused only on interventions which will have the greatest impact on farm productivity.

2. FSP usually needs to receive greater emphasis in harsh environments since there generally are support systems problems which limit the possibilities for increasing farm productivity as much or more than an absence of relevant improved technologies. For example, fewer extension workers per household are generally located in harsh environments and their morale is often low. However, development of support systems is difficult since it is unlikely that support system investments will generate sufficient income to pay for themselves. Research is therefore needed on support systems related problems and on the economics of investing in improvements in support systems versus investments in improving agricultural production technologies.

3. The problems of harsh environment zones or countries often go beyond low farm productivity, the focal point of most FS activities. Health and education services, human water supply, transport networks, etc. usually are equally important problems, and are usually exacerbated in such environments. Therefore, it may not be tenable to approach FS work "with a predetermined focus" (Norman and Collinson, 1985), ignoring the larger context of farmer welfare. Further, in terms of FS management, it can be difficult to draw a dividing line between FS activities of interest to a ministry of agriculture and use of the FS approach as a general method for setting and achieving development priorities.

4. There are generally not many technologies already on the shelf to select for alleviating the identified constraints of farmers. Consequently, rather than a concern with quick results, the orientation of FS work in harsh environments will usually need to be modified to one of building toward significant results following a 10 to 15 year investment in FS work. It is generally necessary to accept incremental, evolutionary changes.

When there are not technologies on the shelf, complementary relationships with experiment station based research are critically important to FS work, adding another dimension to FS management. Not only does FSR&E need to influence the research programs of experiment station based scientists, it may be necessary for them to do some technological developmental work on farmers' fields. Thus, FS management will have to be capable of coordinating collaboration between FS teams and experiment station researchers for the purpose of generating technologies, not just verifying or adapting technologies.

FS TECHNOLOGY DESIGN AND EVALUATION PROCEDURES

As a rule, FS work is focused on a few leverage points where the potential for gains in productivity are the greatest. The entire focus and nature of design work is likely to be different for harsh environment systems, entailing greatly increased attention to the nature of system dynamics. In essence, aspects of activities normally associated with diagnosis and testing become part of an ongoing, iterative technology design process. Several specific observations regarding technology design and evaluation follow.

1. Farmers operating in harsh environments buffer themselves as much as possible against disaster. Three buffering strategies hold important implications for FS technology design and evaluation.

(a) Whenever possible, farmers pursue other activities which have higher or at least more certain returns to resources. For example, in Botswana, because of the risky nature of crop agriculture, farmers keep livestock and brew traditional beer, as well as grow crops. As a result the opportunity costs of intensification of crop production can be high relative to the expected returns. In such situations, technology design and evaluation must involve an assessment of likely returns to investments in risky arable agriculture relative to alternative enterprises. Moreover, in harsh environments where farmers are likely to have relatively low levels of income, non-income sources of utility associated with farming may be important and should be taken into account when designing and evaluating new technologies.

(b) The strategies farmers pursue vary according to how the year develops. Sequential decision-making, in which actions are contingent on subjective expected values of alternative actions, are very important. Thus, to be seen as relevant, technology design must focus on developing a series of contingent recommendations for different years.

In order to develop contingent recommendations, there is a need to understand when and in what form existing and proposed technologies succeed. This necessitates detailed monitoring and analysis of the technical determinants of cropping and livestock outcomes over a multi-year horizon. Secondly, researcher managed and implemented (RM-RI) trials, usually considered a design activity, will often need to receive relatively greater emphasis in harsh environments. RM-RI trials can increase the probability of producing tangible results, particularly during drought years. Thirdly, attention of the social scientists needs to be given to research on farmers' subjective probabilities.

(c) Farmers in harsh environments often minimize inputs in the face of production and/or price risk. Moreover, few farmers perceive arable crop production as a way of producing a surplus. Rather, they attempt to meet some of their subsistence requirements from it. Consequently, a mandate to increase arable production and productivity may not be consistent with overall risk management strategies of farmers. It is important to understand risk management in a multi-year horizon in order to design appropriate interventions. In addition, it likely will be necessary to demonstrate benefits since farmers tend to be skeptical after years of failed extension recommendations and accumulated experiences with failed attempts at increasing production.

2. There tends to be little flexibility in the timing of farm operations in harsh environments. Thus, interventions have to address the issue of breaking bottlenecks rather than exploiting flexibility in the system. For example, Batswana farmers facing low and erratic rainfall must plant when they can, rather than adjusting the time of planting to reduce a weeding period labor constraint. Because of limited flexibility, it may be necessary to introduce row planters so weeding can be done using mechanical cultivation. Breaking bottlenecks often calls for much greater system changes, in terms not only of management but also in terms of resources.

When the first step up the technology ladder involves a lumpy expensive input, such as purchase of a row planter or draft power in Botswana, rather than a divisible input such as improved seed, the ability to adopt those improved technologies which are available often is dependent on resources available to the household . Unfortunately, in many harsh environments including Botswana, there are large variations in farmer resources. Thus, FSR&E activities tend to reinforce income and wealth disparities, making income and wealth distribution assessment particularly important for technology design and evaluation. Furthermore, since ability to adopt improved practices is dependent to a great extent on resources available to the household, endogenous stratification criteria are important for defining research domains (RDs). The discipline of targeting research taking into account household assets is needed since it is often difficult to develop relevant technologies for the poorer farmers.

3. It may be necessary to change several aspects of a system in order to have any effect, rather than one or a few leverage points. This is because it may be necessary to exploit interactions among interventions before the expected value and distribution of outcomes is reasonably large. This poses a problem since it is difficult to continue testing multiple technologies in factorial trials until sufficient confidence is placed on entire system changes. Therefore, it may be necessary to test entire systems, modifying of the IRRI cropping systems approach (Zandstra et al., 1981), with many superimposed trials, rather than use the CIMMYT yes-no and levels trial approach (Byerlee and Collinson, 1980; Perrin et al., 1980). This in itself is a problem since adoption of entire packages is inconsistent with most farm management practices.

4. While the so called leverage rule emphasizes the size of gain from an intervention, returns to research resources depend on the size of gain per adopter times the number of adopters. In harsh environments, where all gains are small in absolute terms, non-leverage interventions may need to receive additional attention, at least at the design stage. Gains in non-leverage areas can lead to additional income and attitudinal changes which make changes in leverage areas more possible.

5. Not surprisingly in harsh environments, there often are strong inter-household linkages serving as informal social support systems. Interventions which increase the returns to particular households may have major negative effects on other households in the community. While this can occur in any environment, the degree is generally more severe in harsh environments. There is a need to pay particular attention to ex ante assessment of technologies impacts throughout communities.

6. In harsh environments there generally will be a low return to investments, so no general rules of 50 or 75% returns can be used.

7. In harsh environments fewer clear trial results are obtained since environmental variation often can dominate treatment effects. If a FS team chooses to manage a trial in order to better control environmental and managerial sources of variation, farmers likely will have too little experience with the technologies to provide evaluation. Therefore, the contributions farmers make to technology evaluation often is less, at least during the early stages of designing and screening technologies. This can be a major problem since, as was pointed out above, non-income sources of utility and farmers' subjective probabilities can exert a large influence on farmers' responses.

8. Most analyses used in FSR&E rely on significant differences in means. There is, particularly in harsh environments, a much greater need to understand distributions. For example, when variation is great, misallocation of resources will not be be captured in production function efficiency analysis and substantial mean differences might be missed in ANOVA of trials.

9. Finally, one might hypothesize that the FS approach, itself, may not provide a sufficiently comprehensive framework for designing and evaluating technologies for harsh environments. Harsh environments often are fragile environments. Interventions which are judged beneficial even from a whole

farm perspective may destablize the environment when adopted by a large proportion of farmers. It may be necessary to adopt more of an ecosystem perspective.

DEVELOPMENT OF A FARMER COOPERATOR APPROACH

In presenting our observations on farming systems in harsh environments we hopefully have clarified why we believe FS work must focus on gaining a detailed understanding of system dynamics. In brief, one could say there are no quick fixes and attempts to promote quick fixes have more potential for harm than they do for benefit.

In this section we turn to a summary overview of the approach we have been using in Botswana to design and evaluate improvements in farm productivity. A key feature of the approach to FSR&E developed by ATIP is farmer cooperator studies. In this approach, research is focused on a limited number of representative households in a few villages. Overtime, these households participate in a number of research activities, including resource monitoring, field monitoring, trials, informal visits to discuss and assess innovations, and a series of single-visit surveys directed at particular topics.

We believe the farmer cooperator approach has several advantages for FSR&E in harsh environments. For example, one is better able to address issues relating to intra-household decision-making and inter-household linkages. Trust is built up leading to improved feedback from farmers. Systems dynamics over time can be observed as they impact on particular individuals and households. Moreover, a farmer cooperator approach represents a compromise reflecting the interests and methodological procedures of agronomists, animal scientists, economists, sociologists and anthropologists. As such a farmer cooperator approach may be appropriate for interdisciplinary FSR&E in less harsh environments as well.

In characterizing our approach, we begin with a summary of the procedures used to initiate FS work. Since the initiation of FS activities in the Mahalapye area in September 1982, more than 20 surveys have been designed and administered, including two multiple-visit surveys. Detailed plot monitoring has been carried out on 200 to 300 plots per season and more than 20 trials have been implemented. Most of these activities have been carried out in cooperation with subsets of a group of 52 farming households. We cannot possibly discuss the objectives and justifications for each of these activities. So, in the second part of the section we merely list the diagnostic and trial activities which have been carried out and discuss characteristics of the farmer cooperator approach.

INITIATION OF ON-FARM RESEARCH

Initiation of on-farm research encompassed several activities spread through the 1982-83 season. Before on-farm research could begin, villages were selected and approved, an exploratory survey conducted, a village sample frame created, and farmer cooperators selected. Later in the season, after on-farm research activities were underway, two surveys were administered which in part served to verify that our villages and farmers were representative of farmer circumstances and practices in the Central Agricultural Region (CAR).

Village Selection

The Project Paper proposed that ATIP research coverage would be limited in terms of extension areas and participating farmers. This research approach is based on the view that differences among farmers within a village, in terms of resource endowments and production practices, can often be more important for adoption of technologies than are differences across villages. This was thought to hold in the CAR where there is a similar agro-climatic environment.

In consultation with representatives from the GOB and USAID, it was decided that research activities would be concentrated in two villages, one each in Mahalapye West and Mahalapye East Districts. In September 1982, three trips were made out of Mahalapye to consider extension areas. Three criteria dominated village selection: a village had to have at least 100 households, sandveld and hardveld soil types would be present, and it should be possible to reach the village within one to one and a half hours.

The two selected villages were Shoshong, in Mahalapye West District, and Makwate, in Mahalapye East District. Both villages are large enough for sampling adequate numbers of farmers to participate in research activities and were felt to be representative of farming systems in the CAR. The soils in both extension areas are hardveld types. A sandveld extension area was not included because of extreme logistical problems and because hardveld dominates the arable sections of the CAR. Since Shoshong is a large village, encompassing two extension areas, it was decided to work just in Shoshong East, one of the two extension areas.

Following initial village selection, approval for village research was sought through village meetings scheduled by village headmen in each area. Approvals for working in Shoshong East and Makwate were received at village meetings held in early October 1982.

Exploratory Surveys

A basic tenet of the FS approach is that research priorities should be established in conjunction with farmers. To gain a preliminary understanding of farming practices and the problems and opportunities faced by farmers, fieldwork began with exploratory surveys in Shoshong East and Makwate during October, 1982.

Exploratory surveys in each village were carried out by two interdisciplinary teams. Each team consisted of at least one agronomist and one agricultural economist. Eight to nine person-days were spent in each village. The interviews were informal and unstructured. However, a checklist of information on practices and problems was compiled during the interviews. Debriefing meetings were held each evening to review findings and identify key issues to pursue in subsequent interviews.

The exploratory surveys provided information for deciding on priority research topics and establishing RDs. Six RDs were identified, groups of farmers with similar problems and for whom the same solutions might be relevant. The RDs were based on whether owned, managed or borrowed versus hired or shared draft power (tractor, oxen or donkey) was used by farmers. The draft arrangement used by a household was hypothesized to be a critical factor affecting its ability to implement timely planting operations. Timely planting was hypothesized to be a key determinant of plant population which is in turn a key determinant of yields.

Sample Frame Census

Once having tentatively set RDs, it was important to verify that the RDs could serve as a viable approach for stratifying farmers in Shoshong East and Makwate. In addition, it was necessary to have a sample frame for future sample selection. Therefore, to provide an empirical idea of the characteristics of farming families in the two extension areas, a 16 question census was administered to the households in Shoshong East and Makwate during the last week of October and early November, 1984. The census included key variables required for stratifying households into RDs. Following a brief training session, nine enumerators seconded from the Central Statistics Office covered both areas in two work-days. Eight additional person-days were spent resurveying households which had been incompletely enumerated the first time through.

Data from the Sample Frame Census (SFC) were initially hand tabulated and findings were used to select ATIP farmer cooperators. Later, after the data were put on the microcomputer, data listings were used in selecting samples for two diagnostic surveys.

Some of the results of the SFC are summarized in Table 1. In Shoshong East, there were 321 households. Makwate is a smaller village with just 161 households. A substantial proportion of the households in both villages were headed by females. The vast majority of households in both areas were involved in crop production. Almost all households engaging in cropping activities managed lands but several households shared land allocation with relatives.

The primary forms of traction in Shoshong East were cattle traction and tractors. While cattle traction was the dominant form of traction at the beginning of the 1982 season, nearly a third of Shoshong East households primarily used a tractor traction. (There has been a shift toward tractors since the 1982-83 season due to drought.) Makwate was and is a donkey village. Until the beginning of the 1985 season, very little tractor traction was used. Taking both villages together, about half the households primarily used cattle and the others were approximately evenly divided between donkeys and tractor.

Many recommended practices taking hold in other areas of Botswana have not made much progress in the Mahalapye area. This was reflected in the almost exclusive use of broadcast planting in both areas. The traditional nature of crop production in Shoshong East was reflected in the small proportion of households that had fenced their lands. In Makwate, a majority of households had wire fencing.

While most households in both areas engaged in crop production, arable agriculture was but one activity for essentially all the households and a minor one in many respects for most households. Livestock were more important than crop production for most of the households, particularly in Shoshong East. More households owned cattle in Shoshong East than in Makwate and the size of cattle herds was larger. In addition to livestock activities, half the households said they derived income from village activities such as selling beer or had income from outside the village, primarily remittances from relatives working outside the village. Most of the other households said they they had income from both inside and outside the village. Only a small proportion of households said they had no other source of income than crop production. (The Makwate figure in Table 1 probably is accurate for both villages since the Shoshong East estimate did not hold up under subsequent surveys and rechecking.)

Farmer Selection

The selection of farmer cooperators is perhaps the most crucial step in a farmer cooperator approach. When selecting a relatively small number of farmers to serve as cooperators, they should be representative of the population with respect to the primary research agenda. In order to make sure households representing each RD were included, we stratified our population before selecting cooperators within in strata. The relative number of households selected in each strata was determined by the relative number of households in each strata in the population as a whole so results would not have to be weighted when presenting findings for each or both villages. It was decided to select independent samples for the on-farm trials and the resource monitoring survey, so that results of the resource survey would not be affected by adjustments in resource use patterns stemming from participation in RM trials.

To begin the selection process, results from the SFC were tabulated and the proportions of the population falling in each research domain calculated for each village. It was decided that ATIP would be able to work with approximately 25 households in the on-farm trials program and 25 to 30 in the Multiple-Visit Resource Use (MVRU) Survey. The size of the MVRU sample was based on an assessment that each of three enumerators could interview five households a day, twice a week, with one day for re-contacts.

To select farmers, the following steps were taken. First, the total number of farmers to be included for each sample was multiplied by the proportional representation of that domain in the population. For example, if 10% were to be donkey hirers, then we were to select 3 donkey hiring households (0.1 x 30). Second, the listings of households from the SFC were divided into the RDs. Third, households in each RD were randomly selected from the stratified listings. Fourth, each household was interviewed from one to three times to confirm that information from the SFC was correct, farmers understood the nature of the program, and farmers were willing to participate on a long term basis. If farmers were not interested in participating, that household was rejected and the next household on the list contacted. Sometimes several visits were made in order to reduce the chance of rejection because farmers were merely intimidated.

Some adjustments were made in the course of selecting each sample. For the trial cooperators, cell proportions were adjusted slightly to make sure there was minimal representation of all domains (except tractor owners), to have replications. Second, the trials program required that farmers had fenced fields, and this may have led to a slight upward bias in the relative wealth of farmers in the "trials" sample.

For the MVRU sample, it was decided to subdivide RDs into poor vs. rich (based on cattle ownership) and male vs. female headed households. Again, population proportions were used to determine how many male vs. female households and rich vs. poor were to be included in each cell. Second, households with only one or two members were not included, since we wanted a perspective of resource allocation in households, not just for individuals. Third, a retrospective survey was administered at the time households were interviewed. A couple of farmers were rejected because they did not think it important to recall resource use information. Fourth, it was necessary to cluster the sample in Shoshong East since enumerators were to bicycle to the fields for interviews (more than 10 kms. from the village). Therefore, households having extremely distant fields (more than 25 kms.) were not considered. Once most farmers had been selected, clusters were filled out clusters by making contacts in the lands area themselves. We drove through the targeted areas, interviewed farmers at randomly encountered compounds, and included the household if it fit our quotas based on traction, draft access, sex of household head, and cattle ownership. It was not necessary to cluster in Makwate, since most fields are quite near the village.

Nearly two months were spent on farmer selection (and the retrospective survey). By the middle of December 1982, 52 farmers cooperators had been selected, and both trial and survey activities initiated. The representation in terms of sex of household head, type of traction and draft access was quite close. Cattle ownership representation appeared to be off somewhat but, in the course of our farmer selection interviews, we found this was due to unreliable results of the SFC with respect of cattle ownership rather than a feature of our cooperators sample. Specifically, many farmers with few cattle claimed they had no cattle in the SFC.

Verification Surveys

Since research was centered on a small number of cooperators in two villages, it was important to make sure those cooperators and villages were typical of the wider population. Therefore, two surveys which had as one primary objective verifying that our primary research villages and farmer cooperators were representative were designed and administered during the first year. The two verification surveys were the Crop Management Survey and the Agricultural Demonstrator Survey.

The primary objective of the Crop Management Survey, administered in May and June 1983, was to provide an overview of farming practices and farmers' problems and preferences in Shoshong East and Makwate. Sample verification was a secondary objective. For this reason, the topics covered in the survey extended beyond those necessary for sample verification. The survey instrument was a single-visit questionnaire with seven sections: (a) household profile, (b) plowing situation, (c) crop enterprises, (d) crop husbandry, (e) resource constraints, (f) farming hazards, and (g) food supplies and preferences.

The questionnaire was administered to MVRU and Trial farmers in both extension areas. In addition, 66 randomly selected farming households were interviewed: 38 in Shoshong East and 28 in Makwate. The sample frame for selecting farmers was the SFC. The randomly selected households made it possible to derive descriptive statistics for each extension area and to test the hypothesis that structural characteristics of the MVRU and Trial households were not significantly different from other households in Shoshong East and Makwate.

Summary results comparing characteristics of ATIP cooperators with randomly selected households in Shoshong East and Makwate are presented in Table 2. As can be seen, there were very few characteristics which differed between ATIP cooperators and the random sample. Although not significantly different, tractor use and the number of cattle owned were greater among ATIP cooperators. This largely reflects the fact that the proportion of farmers coming from Shoshong East, a livestock oriented village, was larger in the ATIP sample. While differences in cattle ownership were not statistically significant, one could reasonably infer from the combination of differences in cattle owned and equipment owned that ATIP farmers probably had slightly greater assets than did the random sample farmers. Any differences were not reflected in traction use, household demographics, land resources, or consumption.

The primary purpose of the Agricultural Demonstrator (AD) Survey was to assess the extent to which problems identified in Shoshong East and Makwate were typical of problems throughout the CAR. A survey of ADs was thought to be a more cost and time effective means of gaining a preliminary farming systems profile than would have been a survey of a randomly selected sample of farmers from throughout the CAR. The survey had two additional objectives: (a) to gather information on activities of ADs and constraints on their effectiveness; and (b) to provide an opportunity for interaction between ATIP researchers and ADs of the CAR.

In March 1983, a questionnaire was distributed to ADs in the CAR at their monthly management meetings. There were five sections to the questionnaire: (a) AD situation and activities, (b) farming systems profile, (c) institutional issues, (d) AD perceptions and attitudes, and (e) rankings of problems and objectives. ADs were requested to mail-in the completed questionnaire. Eventually, questionnaires were received from 52 of 54 ADs in the CAR. After his or her questionnaire was returned, each AD was interviewed in order to eliminate as many mistakes as was possible.

The main results of the AD survey with reference to the verification objective were: (a) there were relatively few differences between extension areas in terms of crops grown and crop management practices; and (b) variability among enumeration areas within districts was much greater than the differences among districts. The survey results supported the view that it should be possible to carry out farm management research and on-field testing of improved technologies, at least in the RM-RI and RM-FI stages, in just one or two districts. The survey also showed that villages clearly differ in key aspects, such as dominant type of traction used. If FS work was to be concentrated in only a few villages, it would be necessary that those villages capture the configuration of key village characteristics. Fortunately, the survey showed that Shoshong East and Makwate together well represented the most common types villages in the Central Region.

SUBSEQUENT DIAGNOSTIC AND TECHNOLOGY GENERATION ACTIVITIES

By the beginning of 1983, the structure of our farmer cooperator approach was established. The verification surveys were administered and at least partially analyzed by the middle of 1983. At that point, after our first season, we decided that the harsh environment in Botswana required a FS approach that included ongoing system diagnosis, involving monitoring of income and resource flows and technical plot monitoring, and a broadly focused trials program.

Once having accepted the need for information on income flows, resource use patterns, and the technical determinants of cropping outcomes, the question became one of developing a methodology which is consistent with the pragmatic aims and budgets of FS work. In developing an appropriate FS approach, we first had to decide on principals governing sample size and composition. Specifically, we had to decide: (a) whether to shift from a small sample approach to a larger sample of farmers; and (b) whether to continue with the same cooperators from year one or to select a new set of cooperators.

The decision on sample size was relatively easy. We decided that a small sample, once we knew it was representative, was preferable to a large sample for several reasons:

(a) Measurement errors can be reduced and unique features of households affecting observed patterns of resource flows can be easily identified.
(b) Diagnostic surveys could serve as a means of verifying and further analyzing observations based on personal contact, rather than serving as a substitute for personal contact.
(c) Enumerators and farmers would soon became familiar with the questions, reducing researcher time necessary for checking data.
(d) If properly selected, small samples can represent the range of farmer circumstances.
(e) Responses of new farmers to technologies can always be assessed in verification trials after initial testing activities have taken place.

Several features of farming systems in Botswana also mitigated against shifting to a new group of farmers in year two. Some of these have been discussed in general terms above as observations about harsh environment farming systems. Four considerations were particularly important:

1. Agricultural production is just one source of household income. Wage employment, remittances and even traditional beer brewing can be as important sources of income. Information on some of these income sources is sensitive and requires repeated visits by individuals who know and are known to each household. The quality of information is improved as trust is established.

2. Households are managed by multiple, interacting individuals. Even when there is a male head of household, women and children have their own activities and make their own decisions. An understanding is needed of intra-household dynamics over time in order to appropriately design and evaluate technologies.

3. Most households have members spread over several locations. In addition to field and village compounds, one must take into account household members living at the cattle post or working at jobs outside the village area. Because of the complex and dynamic structure of households, we felt it was

necessary to identify and assess household composition and circumstances on a case by case basis.

4. Rainfall in the 1982-83 season made it impossible for all but a few farmers to produce crops or to maintain their animals in reasonable condition. Still, certain farmers were notably more successful than others. It emerged as a top priority to be able to identify the relative productivity of farmers with different household circumstances in different years and the adjustments different farmers make to changes in environmental circumstances.

Consequently we decided to continue with the same farmers in the second year of the program, and again during the third year. A list of the FS activities of the Mahalapye team through the 1984-85 season is presented in Table 3. As can be seen, farmer cooperators were the focal point of nearly all activities.

Between 1983 and 1985, several features of our farmer cooperator approach became more clearly defined. In terms of initiating FS activities, the key features of the approach, discussed above, are the village focus, reliance on a small sample of farmers for repeated activities, and the procedures used to select farmers and verify the representativeness of our samples. As our program evolved, seven additional characteristics of a farmer cooperator approach emerged with respect to diagnostic and technology generation activities:

1. We increasingly relied on purposively selected subsets of our cooperators and particular individuals within households for technology design and testing activities. For example, if an intervention required a decision about what seed to use, we approached the women in households who were known to be responsible for that decision. Similarly, trials requiring multiple tillage operations were implemented by individuals known to be active farmers and interested in intensifying their arable crop production enterprise.

2. The independent samples of cooperators were integrated beginning the second year, to the extent that all farmers were given the opportunity to participate in trials. Cooperators appreciate seeing trial plots in their fields, even though they are only "tests, not demonstrations." By integrating the samples, we had more representatives for different sets of farmer circumstances.

3. We phased down our contacts, particularly with the MVRU sample, in order to reduce demands on the cooperators. For example, in year two the number of questions asked was greatly reduced. In year three, a purposive subset of only 13 household participated in the MVRU survey, and the survey was cut back to concentrate only on household income activities. Also, after the second season, several Trials cooperators with a marginal interest in arable production were no longer active in the trials program but continued to be interviewed in various subject surveys.

4. One of the key features of the approach was the periodic collection of some key data. In each season we collected data on plowing situations, including types of traction, draft access, and timing and amount of plowing. For some farmers we have multiple year profiles of household demographics, farm fixed capital and livestock inventories. Synthesizing information about

changes in profiles over time for different categories of farmers provided an important perspective on farming systems in the Mahalapye area.

5. Reliance on cooperators allowed us to minimize the use of enumerators. At the beginning, two village staff were responsible for the MVRU survey and two others were responsible for trials and plot monitoring. By the third year, only two enumerators were required for both the plot monitoring and the MVRU survey since the sample sizes for both activities were greatly reduced. All other survey activities and the initiation and management of trials were carried out by a small group of researchers, a maximum of five, based at Mahalapye.

6. An important factor relating to the credibility of the approach was the increasing use of noncooperators under particular conditions. For example, during the recently completed season we conducted a study on intra-household decision-making and farmers' perceptions of practices ATIP is engaged in testing. We felt our cooperators might have become be atypical with respect to views on arable production technologies, so we relied instead on the set of randomly selected farmers which participated in the 1983 Crop Management Survey. This gave us a nice compromise. We were able to evaluate changes in circumstances and attitudes overtime but did not have to worry about sample bias. Another circumstance where we turned to noncooperators was for implementation of FM-FI trials. Some trials require relatively little researcher involvement and some involve assessments of farmers' abilities to implement a technology. In either situation, we found it useful to use noncooperators to increase the likelihood that our managerial assessments were not distorted by any behavioral modifications of our cooperators.

7. A minor but important aspect of the approach was provision of some services to the cooperators. This was limited to provisions of seed for most trials, occasional loans of equipment when it is needed, inexpensive watches to help farmers report on labor use, information on agricultural programs, and participation in field days. Farmer cooperators should be able to realize some benefits for all the help they give FS programs.

CONCLUSIONS

In this paper we tried to identify unique features of farming systems in harsh environments and implications for FS program goals and appropriate FS technology design and evaluation procedures, based on our experiences in Botswana. We believe many of our observations are relevant for FS programs operating elsewhere in harsh environments and perhaps even for programs in more equable environments. We then turned to a description of the development of a farmer cooperator approach by the Mahalapye team of the ATIP project, as an example of an approach we think is particularly suitable for FS programs operating in harsh environments.

A few points should be kept in mind when evaluating the value and relevance of our approach for other FS programs. First, the approach described is based on experiences of the Mahalapye field team. There are unique circumstances in the CAR which are conducive to a farmer cooperator approach: (a) the combination of vast distances; (b) a relatively homogeneous institutional and technical environment; and (c) large variation in farm productivity associated with assets and draft access.

Second, ATIP is located in the Department of Agricultural Research and the Mahalapye team has a mandate to develop improved arable production technologies. Thus, activities related to livestock, social institutions and extension were included on our agenda because of our observations, presented above, that FS technology design and evaluation activities must be broadly focused. Even more time might have been spent on these activities if they had been a part of the mandate.

Third, we do recognize that diagnostic and design research activities have opportunity costs with respect to testing and dissemination. To the extent promising interventions can be identified, a farming system is less harsh, by our definition, and FS work as conventionally practiced becomes an effective alternative.

Fourth, team members were forced early on to take a long run perspective, rather than focus on short run changes in farming systems. Shifting away from a preoccupation with the short run had perhaps the most profound effect on the approach we have used for FS work but this may not be an option for other FS programs.

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Table 1: HOUSEHOLD CHARACTERISTICS IN SHOSHONG EAST AND MAKWATE, OCTOBER 1982

VARIABLE	SHOSHONG EAST	MAKWATE	ALL
Households	321	161	482
Average Household Size	6.4	7.4	6.7
Percent: Female Headed	36	41	38
Engaged in Crop Production	80	77	79
Managing Lands	71	72	71
Primary Traction (Percent Using):			
Cattle	64	17	48
Donkeys	3	81	29
Tractors	33	2	23
Fencing (Percent With):			
Wire Fencing	16	62	31
Bush or No Fencing	84	38	69
Percent Broadcast Planting	97	97	97
Percent Owning Cattle	60	47	56
Average Cattle Herd Size:			
Cattle Owners	36	19	30
All Households	25	12	21
Access to Income (Percent of Households With Income From)			
Inside Village Activities	25	41	30
Outside the Village	20	21	20
Inside and Outside Village	39	37	38
Neither	16	1	12

Source: 1982 Sample Frame Census

TABLE 2: ATIP COOPERATORS COMPARED TO RANDOM SAMPLE

VARIABLE	ATIP	RANDOM
DEMOGRAPHIC:		
Percent Male Headed	61	59
Year Head Born	1930	1929
Members > 16 Years	4.7	4.6
Members < 15 Years	4.7	4.2
Active in Cropping	2.8	3.1
Have Wage Employment	1.2	1.4
NUMBER OF INCOME SOURCES	2.9	3.1
CATTLE OWNED	41	25
NUMBER OF IMPLEMENTS	1.4	0.9/a
LAND:		
Years Field Cultivated	22	21
Seasons in 10 Use All Land	4.5	5.0
PRIMARY TRACTION:		
Donkeys	34/b	41/b
Cattle	36	38
Tractors	30	21
PRIMARY ACCESS TO DRAFT:		
Own	56/b	52/b
Borrow, Manage, Mafisa	6	11
Hire	29	29
Cooperative Arrangement	8	9
AMOUNTS OF PLOWING:		
Days Plowed '82-83	5.7	4.7
Days Plowed Good Season	11.3	8.8
Acres Plowed '82-83	9.1	8.6
Acres Plowed Good Season	16.0	15.5
CONSUMPTION:		
Bags Grain Per Month	1.3	1.2
Days Drink Milk Per Month/c	14	13
Days Eat Gathered Food/c	19	23
Consume Goat Meat Per Month	3.0	3.9
Consume Beef Per Month	5.1	4.5

Source: 1983 Crop Management Survey

a. Significant difference at .95 confidence level.

b. Percent of households.

c. Frequency refers only to the cropping period for these are seasonally consumed.

Table 3. Follow-On Diagnostic and Trials Activities, 1982-1985.

ACTIVITY	SAMPLE	FOCUS
1982-83 SEASON		
WHOLE FARM STUDIES:		
(a) Multiple-Visit Resource Use Survey (MVRU)	27 Households*	Cash Flows, Labor Use, Income & Household Maintenance Activities, Market & Non-Market Exchanges
(b) Technical Plot Plot Monitoring	192 Plots on 23 Fields*	Farmer Inputs. Soil & Climatic Conditions, & Crop Response by Plot
ON-FARM TRIALS:		
(a) Evaluation of Planting Methods	15 Sites*	Sebele Plow-Planter & Row Planter; Third, Furrow Hand, Harrow
(b) Tillage System Investigation	Multiple Strips in Two Fields*	Double Plowing, Early & at Planting
(c) Sorghum Intercropping	RM-RI Trial on one Field	Establishing of Late Season Undersowings
SUBJECT SURVEYS:		
(a) Draft Arrangements	About 70 Households*	Plowing Situation; Interhousehold Arrangements
(b) Agricultural Demonstrator	54 ADs	Activities of ADs; Regional Profile of Farming Systems
(c) Crop Management	116 Households	Crop Enterprises; Crop Husbandry; Resource Constraints; Hazards; Food Preferences
(d) Within Field Variability	200 Field Sites*	Soil and Topographical Characteristics & Associated Crop Growth
(e) Weed Survey	50 Farmers*	Weeding Practices and Problems
1983-84 Season		
WHOLE FARM STUDIES:		
(a) MVRU	26 Households*	(See Above)
(b) Household Inventory	26 Households*	Household Census; Livestock Inventories; Farm Fixed Capital
(c) Plot Monitoring	47 Farms*	(See Above)
ON-FARM TRIALS:		
(a) Effects of Early Tillage	2 Reps on Each of Two Farms*	10 & 20 cm Early Plow, Early Harrow & No Early Tillage
(b) Effectiveness of Sole Plowing	9 Reps*	Modified Early Plowing & Planting Method Comparison
(c) Draft Team Management	3 Donkey Teams 2 Oxen Teams*	Energy Supplements on Plowing Days
(d) Evaluation of Benefits	2 Reps Plowed on 13 Plots 5 Plots Harvest*	Relationship Between Early Plowing & Crops; Response to Fertilizer

Table 3 continued.

(e) Cowpea and Mixed Cropping Comparison	16 Farmers*	Blackeye, ER-7, Tswana; Sorghum Mixed wtih Populations of Tswana
(f) Bird Scaring	4 Sites*	Installation of Polyethylene Hum Line
(g) Seed Treatment	12 Farmers*	Captan and Malathion Treatment of Local Seed Lots
(h) Sebele Plow-Planter	3 Farmers in an FM-FI Approach*	Animal Drawn 2 Furrow Unit; Tractor Drawn Unit
SUB-STATION TRIALS:		
(a) Local Sorghum Germplasm Evaluation	69 Seed Lots	Locally Selected Sorghum Populations
(b) Dual Purpose Cowpeas	32 Lines	Variations in Lines of Tswana Cowpeas
SUBJECT SURVEYS:		
(a) Cropping Plans	45 Households*	Planned Enterprises & Husbandry Practices; Seed Availability
(b) Post-Tillage Weeds	59 Plot Situations*	Weed Development on Different Fields
(c) Soil/Root Profiles	15 Fields*	Root Penetration by Soil Strata; Soil Composition Analysis
(d) Institutions, Services & Infrastructure	Shoshong and Makwate Villages	Village Markets & Prices; Government Services; Local Institutional Structure
(e) Cowpea Baseline	51 Households*	Cowpea Husbandry; Product Utilisation; Consumption Patterns
<u>1984-85 SEASON</u>		
WHOLE FARM STUDIES:		
(a) MVRU Households	13 Households*	Successful and Commercial Beer Brewing
(b) Activity Survey	50 Households*	Qualitative Profile of Labor Use
(c) Inventory Survey	50 Households*	(See Above)
(d) Plot Monitoring	13 Farms*	(See Above)
ON-FARM TRIALS:		
(a) Commercial Steps in Technology	5 Sites*	Assessment of Technical Package for Farmers Willing to Substantially Increase Arable Production Inputs
(b) Ridge Plowing	1 Site*	Technical Evaluation of the Ridge Plow
(c) Draft Management	1 Village*	Farmer Assessment of Improved Draft Management Scheme
(d) Intensive Production Plots	12 Farms*	Intensified Inputs Sometimes with Waste Water
(e) Undersowing	13 Farms*	To Incorporate Different Planting Dates of Compatible Crop Components on a Single Plot
(f) Tillage Planting	8 Farms*	Test 2 Tillage/Planting Schemes

Table 3 continued.

(g) Alternative Planting	4 Farms*	Technically Evaluate Sehele Plow Planter & Hand Planting
(h) Crop Seeding Comparisons	17 Farms*	Compare Cropping Options to Seeding Under Traditional System
(i) Cowpea	8 Farms	Look at Cowpea Variety/Tillage Interactions
SPECIAL STUDIES:		
(a) Trader Baseline Survey	163 Traders	Understand Market Structure & Assess Marketing Structure in Central Ag. Region
(b) Farmer Decision Studies	55 Households*	Understand Inter- & Intra-Household Patterns of Decision Making -- 5 Surveys

* Included cooperator farmers.