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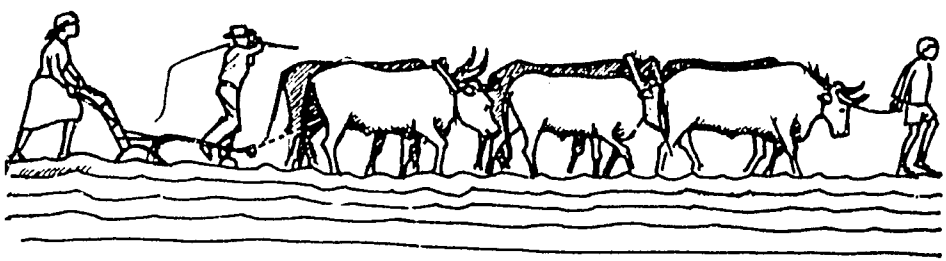
AGRICULTURAL TECHNOLOGY IMPROVEMENT PROJECT (ATIP)

TECHNICAL SUMMARY OF ATIP'S ACTIVITIES 1982-90: RESEARCH RESULTS

ATIP RP-5



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AGRICULTURAL TECHNOLOGY IMPROVEMENT PROJECT

ATIP

TECHNICAL SUMMARY OF ATIP'S ACTIVITIES, 1982-90:

RESEARCH RESULTS

ATIP RP 5

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PREFACE

The Agricultural Technology Improvement Project (ATIP) has had primarily a farming systems research orientation and has been in operation for a period of eight years (1982-1990). The project has been sustained through funding on the part of the Government of Botswana (GOB) and the United States Agency for International Development (USAID). The USAID funding has been mainly channelled through the contractor, the Mid-America International Agricultural Consortium (MIAC) with Kansas State University (KSU) as the lead institution. With the scheduled end of the KSU/MIAC contract in September 1990, it was considered desirable to produce a Technical Summary of ATIP activities. This compilation is available in three parts. These are as follows:

(a). Technical Summary of ATIP Activities, 1982-1990: Research Results [ATIP RP 5].

(b). Technical Summary of ATIP Activities, 1982-1990: Promising Guidelines [ATIP RP 6].

(c). Technical Summary of ATIP Activities, 1982-1990: Research Extension Liaison Office Achievements [ATIP RP 7].

This report is the one listed under (a) above.

It is anticipated that report (a) will be of most relevance to those interested in research, while report (b) will be more relevant to extension staff interested in undertaking widespread testing of promising technologies and approaches. Report (c) will be of interest to those concerned about fostering linkages between research and extension by means of a Research Extension Liaison Office (RELO).

The staff of ATIP would like to express their appreciation for the support given by the leadership in the Ministry of Agriculture, by USAID personnel, by MIAC/Kansas State University staff and, above all, by the many farmers who have enthusiastically participated in the multiple trials, studies, surveys and training courses undertaken by ATIP, often in association with other agencies in the Ministry of Agriculture.

This particular report 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. Mmolawa.

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CHAPTER 1: INTRODUCTION

1.1 ATIP BACKGROUND

1.1.1 HISTORY

1.1.1.1 General

Agricultural research in Botswana dates back to the 1930's. Initially it was confined to research in the animal production and rangeland areas, but in 1945, crop strategy research was added. Over the years a large number of topics were investigated [Addy, Farrington, Gollifer, Hunter, Stewart-Jones and Sweet, 1987] and, as a result, by the early 1970's, it was felt that it should be possible to significantly increase agricultural production in the country, if the technologies were adopted by a large enough number of farmers [Addy et al., 1987]. Apparently 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, the decision was made to initiate testing on farmers' fields. As a result of this, two projects came into existence in the mid-1970's -- namely EFSAIP (the Evaluation of Farming Systems and Agricultural Implements Project) and IFPP (the Integrated Farming Pilot Project).[1] From their early 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) which were combined to form a package, based on a multi-purpose toolbar, had some limitations. However, because of the feedback process there were improvements in individual component technologies.

During the next few years there was an expansion in the development of what increasingly became farming systems research (FSR), with the initiation of the Agricultural Development for Ngamiland Project (ADNP)[2] 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 FSR approach, even though some did not start out as FSR projects. As a result, they have all been involved in designing -- with the aid of technologies developed by on-station research -- solutions to problems that have been identified with the help of farmers. Those potential solutions have then been tested, together with farmers, on their fields.

In general, apart from IFPP (FSSR) and to a lesser extent ATIP and MDP, most of the projects have concentrated on crop 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 FSR teams, it has tended

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[1]. The name IFPP was later changed to Farming Systems Southern Region (FSSR).

[2]. This was later known as the Agricultural Ngamiland Development Project (ANDP).

to concentrate on the crop/livestock interface (harness/yoke equipment, feed -- both specially grown and crop residues -- winter fattening of cattle, and small ruminants).[3]

In the early days, much of the support for FSR activities in Botswana was provided by various donor agencies (i.e., British, Swedish, American and German). However, in recent years the proportion of funding met by the Government of Botswana (GOB), has been steadily increasing. Currently in 1990, farming system teams are operating in the Kanye, Mahalapye, Francistown and Maun areas.[4]

Recently decisions have been made by GOB to institutionalize on-farm research (i.e., most of which is conducted as FSR), to locate all the FSR teams under the umbrella of the Department of Agricultural Research (DAR), and to reorganize the research programs into a number of multi-disciplinary commodity/subject research teams. These decisions all bode well for a continuation of FSR activities and for strengthening the research program of the department through improving the interaction, not only between the FSR teams but also between on-farm and station-based research. In addition, in recent years, links -- although still largely informal -- have been strengthened between research and extension, particularly in the regions where FSR teams are located. Another positive trend has been improved interaction between FSR teams and farmers. Links between FSR teams and planning have been largely one of responding to requests for help from the planning authorities.

1.1.1.2 ATIP

The United States contractor for the USAID-funded part of ATIP has been the Mid-America International Agricultural Consortium (MIAC) with Kansas State University (KSU) as the lead institution. The stated purpose of the project was to improve and expand the capacity of the Ministry of Agriculture's (MOA) research and extension programs to develop and effectively extend farming system recommendations relevant to the needs of resource poor farmers. The project paper indicated that the project was essentially institution building in nature, requiring a long-term commitment in participant training and technical assistance. As a result of these efforts, it was hoped that catalytic roles could be played in institutionalizing FSR in Botswana, and in helping research to respond to the needs of limited resource farmers.

To fulfill the above aims, two farming systems teams were set up, one at Mahalapye (starting in September, 1982) and one in Francistown (starting in August, 1983), a Research-Extension Liaison Officer (RELO) was posted with extension at MOA headquarters in Gaborone, and the Team Leader was posted at the research headquarters at Sebele. To complement the technical assistance team -- consisting most of the time of seven individuals -- have been counterparts from DAR, Department of Agricultural Field Services (DAFS)[5] and the Division of Planning and Statistics (DPS). The main disciplines represented in the project have been agronomy and agricultural economics, together with

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[3]. 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.

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

[5]. The department has recently been split in two: the Department of Crop Production and Forestry, and the Department of Animal Production and Health.

some animal science representation. In addition, during the project, ATIP funds have been used to partially support long-term US technical assistance provided under two Collaborative Research Support Programs (CRSPs), namely Bean-Cowpea, and to a much greater extent, Sorghum-Millet (INTSORMIL).

The initial length of the project, which started in August 1982, was scheduled for five years but through no-cost extensions was later extended to eight years. USAID will plan on partially supporting one position after the USAID-funded technicians depart in September 1990, while INTSORMIL will also continue funding one position.

As far as ATIP activities are concerned, the primary target group has been defined as those cultivating from one to ten hectares and having less than 40 head of cattle. It has been estimated that up to 40 percent of these households are headed by women [ATIP RP 2, p. 8].[6] Substantial numbers of surveys, studies and trials have been carried out, on and with, representative farmers in this heterogeneous target group. In concurrence with the project's mandate, a great deal of emphasis in ATIP's work has been placed on arable agriculture. Nevertheless some work has been devoted to the livestock arena. Because of the limited availability of research resources in this area, livestock work has had to be very selective.

1.1.2 SELECTION OF VILLAGES[7]

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 Agricultural Region and the other in the Tutume Agricultural District. In the Central Agricultural Region, Mahalapye was chosen by the ATIP staff, in consultation with the Director of Agricultural Research, because of the existence of an experiment station at that location, and for logistical reasons.

Over the years, research activities have been largely confined to three villages in each area. This was done for the following reasons:

(a). Concentrating activities in a limited number of locations simplified matters logistically, and also helped improve the return from research resources -- in terms of time, staff and financial costs.

(b). It was believed that, since there is little agro-climatic variation within the working area of each region, the variation in resource endowments and production practices of different farmers within villages was likely to be as great as between villages. This meant that representatives of different types of farmers in each working area could be captured by confining activities to a limited number of villages. Villages were selected more on the basis of size and accessibility, and the range of farmers was confirmed during exploratory surveys.

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[6]. See Appendix D for full citation of papers produced by ATIP personnel.

[7]. More detailed information on the procedures for selecting the villages and farmers (discussed in Section 1.1.3) can be found in ATIP RD 83-1 [pp. V13-17], ATIP RP 1 [pp. 12-22], ATIP RP 2 [pp. 15-22], Baker [1987, pp. 24-27], and ATIP PR F83-1.

The villages in each region were therefore selected after:

(a). Reviewing secondary information available on the areas.
(b). Extensive consultations with extension and other informed regional, district and local staff, including village headmen and villagers in the areas.
(c). Visits by ATIP staff to a number of villages.
(d). Being satisfied that the villages were representative of others in the area, reflected the diversity of conditions existing in the area, etc.

Approval for working in the villages was obtained from relevant government officials, and at village **kgotla** meetings chaired by village headmen.

There is the possibility of some bias in the initial selection of the villages, although later studies did appear to indicate that the variation between and within the selected villages did reasonably capture the variation in the working areas as a whole [ATIP PR M84-2; ATIP WP 3]. The selected villages on which most of the observations in this report, are based, are given in Table 1.1. In the same table are presented some major characteristics that over the years have helped explain some of the differences in the results from the various villages.

TABLE 1.1: SOME DISTINCTIVE CHARACTERISTICS OF THE ATIP VILLAGES

AREA	DISTRICT	VILLAGE	SIZE AND ACCESSIBILITY[a]	DISTINCTIVE CHARACTERISTICS
Francistown	Tutume	Mathangwane	Large, excellent	Urban influence; tractors common
	Tutume	Marapong	Medium, good	Progressive village; communal activities common
	Tutume	Matobo	Small, average	Traditional orientation; animal traction dominates
Mahalapye	Mahalapye West[b]	Shoshong	Large, good	Good amenities; lands and cattle posts very dispersed; many tractors
	Mahalapye East[b]	Makwate	Small, average	Donkey traction dominates
	Palapye	Makoro	Small, excellent	Dispersed settlement pattern; mainly animal traction

a. The larger and more accessible villages tend to have greater numbers of and better amenities, such as shops, bottle stores, restaurants, etc. Shoshong and Marapong have Cooperative Societies, while Marapong also has a Development Trust and a Small Ruminant Farmers Group.
b. Mahalapye West is now sometimes referred to as Mahalapye, while Mahalapye East is often called Machenang District.

1.1.3 SELECTION OF COOPERATING FARMERS

At the outset ATIP made an effort to obtain some idea of the variability in terms of resource endowments and production practices of the farming populations in each of the villages. Usually this was accomplished by an initial literature review, followed by discussions with knowledgeable individuals, and informal (Exploratory) and one-shot Sample or Census Frame Surveys. The idea behind this was to provisionally stratify farmers into homogeneous sub-groups (research or recommendation domains) on the basis that farmers within these groups had the same problems and the same potential solutions to those problems [ATIP RP 3, pp. 27-29]. This was important to ensure that later research activities of ATIP could address the needs of the different types of farmers found in the villages -- hereafter called the ATIP villages. In general terms, the recommendation domains in ATIP work tended to be determined by the ability to pursue timeliness of operations to take advantage of the soil moisture when it was available. Consequently, in much ATIP work,

farmers have tended to be stratified according to:

(a). ***Francistown.*** Wealth -- as measured by the number of cattle owned.
(b). ***Mahalapye.*** Type and degree of control of draft -- as measured by owning or hiring tractors, oxen or donkeys.

There was a great deal of similarity between the two types of stratification. For example, wealthy farmers were more likely to own tractors and therefore were likely to be better able to ensure timeliness in their operations. In general, little attempt was made to differentiate female from male-headed households since the former represented a higher proportion of the farming households in the poorer strata (e.g., strata where traction was not owned).

With this stratified set of farmers it was then possible to select appropriate farmers with whom to test specific types of technologies, and use as respondents in specific surveys. Various farmer selection approaches have been used over the years -- for example, for the Mahalapye area, see ATIP EP 85-7 [pages 544-546]. Some of these initial cooperators have been involved in ATIP activities for many years -- see, for example, the annual Cooperator Survey undertaken in the Francistown area [ATIP PR F87-1].

The initial cooperators were originally chosen by a stratified random sample approach, subject to the condition that those selected were interested, willing and able to cooperate. However in more recent years, those initial cooperators have sometimes been replaced, complemented or supplemented by additional farmers through:

(a). Purposive selection by researchers interested in obtaining the cooperation of specific farmers because of particular attributes or resources they possessed. For example, their field had a particular soil type, they had a flock of goats, etc. Usually this type of selection occurred for trials that were managed and implemented by researchers (i.e., RMRI trials), and sometimes for trials that were managed by researchers but implemented by farmers (i.e., RMFI trials).

(b). Volunteering by farmers themselves. This was particularly the case in farmer managed and implemented (i.e., FMFI) trials that in recent years have been undertaken through Farmer Groups (see Section 3.2.2 in this report).

1.2 FARMING SYSTEMS RESEARCH METHODOLOGY[8]

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. ATIP has used the term FSW to refer to both the technology and the support system/policy thrusts, and farming systems research (FSR) to signify the technology thrust. In fact, with reference to ATIP, most work has concentrated on the technology thrust, and therefore FSR. Consequently most of this report concentrates on summarizing the

[8]. A much more detailed discussion on the philosophy of, and approach used by, ATIP in FSW is presented in a handbook for FSR recently written by ATIP personnel [ATIP RP 3; ATIP RP 4]. Of particular interest in terms of material presented in this section are pages 6-13 and 31-36.

results of work directed at the technology thrust. However in more recent years increasing attention has been given to dissemination practices as part of the support system.

Very briefly, FSW consists of four steps in the research process (Figure 1.1). These steps or stages are as follows:

(a). ***The Descriptive or Diagnostic Stage*** in which the actual farming system is examined in the context of the physical-biological and socio-economic 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 such strategies comes from experiment station work, researcher managed and researcher implemented (RMRI) type work on farmers' fields, from other farmers, and, of course, from secondary sources.

This stage, in essence, involves an **ex ante** evaluation, from the viewpoint of the farmer, as to whether the proposed technology is technically feasible, economically viable and socially acceptable.[9]

(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 are always undertaken on farmers' fields. All these types of trials may be undertaken by the farming systems 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

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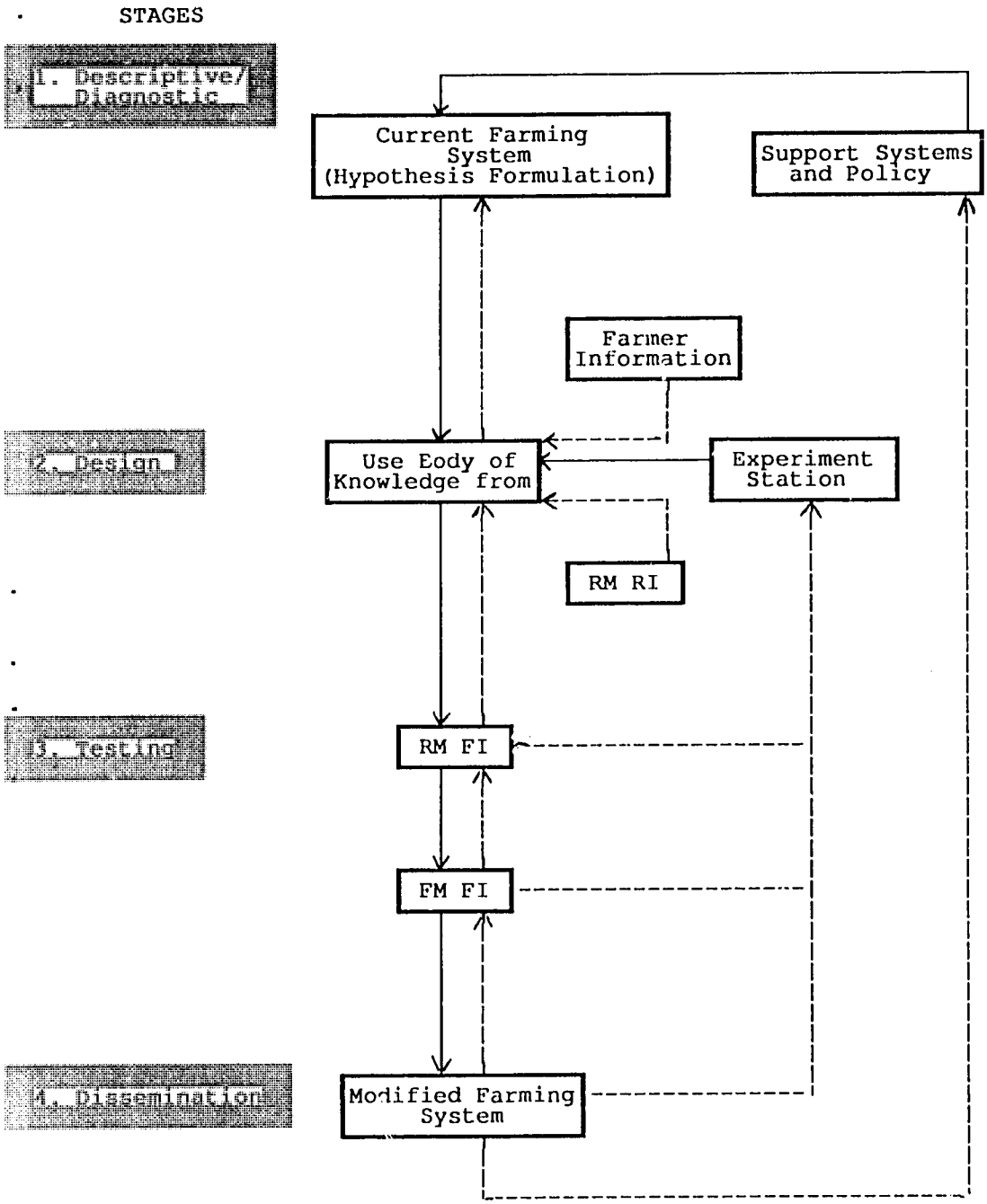
[9]. In addition, particularly from a societal viewpoint, the issue of sustainability is also becoming increasingly important.

FIGURE 1.1: FARMING SYSTEMS WORK



KEY:

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

by farmers may mark the beginning of dissemination activities.

Also, it may not always be necessary to go through all the stages. Farming system 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.

In essence, the farming systems approach involves putting the farmer on center stage, involves working with representative farmers, needs an interdisciplinary approach, is a dynamic and iterative approach and is complementary to -- not a substitute for -- experiment station-based research.

Complementarity with experiment station-based research stems from the difference in characteristics of on-station research, with its emphasis on applied research, and FSR which concentrates mainly on adaptive research. Table 1.2 notes some of these differences and hopefully illustrates why both types of research are essential

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/Rehability		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

Involving the farmer in the research process involves both challenges and rewards. In order to address the needs and interests of both experiment station-based researchers and farmers, ATIP has been careful to differentiate trials undertaken in terms of who manages and implements them, that is, the researcher (technician) or the farmer. A careful study of Table 1.3 indicates that the three major trial types used in ATIP work 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 it 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. It is important to know the type of trial that was implemented in order to be able to assess what the appropriate expectations should be with respect to the interpretation of the results. Obviously for example, cause-effect relationships can be derived in RMRI trials, while farmer attitudes are much easier to ascertain in FMFI trials.

TABLE 1.3: 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	Technical/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/extension

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 there are 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 ATIP EP 89-5.

In this summary report, results presented and conclusions given are derived from all three types of trials, as well as studies and surveys of various types.

1.3 CLIENTS IN TECHNOLOGY DEVELOPMENT

This section is devoted to a brief discussion of how ATIP has conceptually viewed the development of technologies that are likely to be relevant for limited resource farmers, and how the needs of the main clients of on-farm technological research (i.e., farmers and station-based researchers) have appeared to differ.

1.3.1 THE TECHNOLOGY LADDER AND RELATED IMPLICATIONS

ATIP has found it useful, when considering the suitability of technologies for farmers, to systematize thinking in terms of a technology ladder.

From the farmers' perspective, all other things being equal, the type of improved technology that initially is likely to be most acceptable, is that which:

(a). Does not necessarily require great changes.
(b). Can be adopted to varying degrees.
(c). Requires little in the way of extra skills.

Examples that might fulfill the above conditions are divisible inputs such as improved seed, fertilizer, etc. Unfortunately in the harsh climatic environment of Botswana, such a low initial step is rarely likely to be of major benefit because of the need to implement strategies that will alleviate major constraints. For example, the constraint of water availability might need to be addressed first so that the return from fertilizer or improved seed can be ensured. Strategies for bringing about better water availability have revolved around tillage methods to make more water available, and improving timeliness of operations to maximize the use of the water when it is available. There are two types of steps, one involving resources and the other involving the acquisition of skills. For example:

(a). One type of step on the technology ladder requires relatively large changes in the amount of resources used by the farmer. For example, double plowing with broadcast planting, which is one of the simplest tillage practices designed to increase soil moisture availability and lengthen the plow-planting period, requires almost twice as much traction per hectare as the traditional single plowing strategy. A single plowing strategy is likely to be much more popular with farmers in environments where labor and draft are more limiting, than land. Adopting such a strategy therefore implies a fairly major commitment of limited resources on the part of the farmer, thus constituting a fairly large step up the ladder. In addition, the nature of the inputs required are more indivisible and hence bigger, or as economists say, more "lumpy" in nature. In general, every addition of a useful field operation or use of an additional piece of equipment to the system represents a step up the technology ladder.

(b). Another type of step up the ladder requires additional skill such as learning to row plant, and replacing the broadcasting method. Such a step may also require an additional resource commitment from the farmer (e.g., planting resources) or could involve resource savings (e.g., mechanical weeding to reduce weeding labor). Adopting a row planting strategy requires a major commitment from the farmer to learn to correctly use the technology that is new to the system.

In a harsh climatic environment, the relatively large farmer commitments involved in moving up the lower rungs of the technology ladder imply that the challenge of getting farmers to change is likely to be greater than in a more equable climate.

Two issues that have some relationship to the technology ladder concept, and are important when thinking about ways to help limited resource farmers in Botswana, are the following:

(a). ***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, planting sorghum late to avoid a particular disease problem. The decision on which approach to use in dealing with the constraint will depend on its severity, the flexibility that exists within 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 usually 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. Unfortunately under the harsh climatic conditions in Botswana, major emphasis has to be placed on breaking constraints rather than exploiting the flexibility that might exist in farming systems in more equable climates. As a result, changes required on the part of farmers are relatively greater, making steps up the technology ladder somewhat more difficult than for farmers in more favorable climates.

(b). ***Contingency Plans Or Range Of Options.*** The considerable variation in the level and distribution of rainfall between and within years leads to considerable uncertainty as far as farmers are concerned. This lack of predictability means that the strategies farmers pursue vary according to how the year develops. In essence, they employ a decision tree type strategy in which they respond to constraints and opportunities that emerge as the season unfolds. In such situations, no one strategy is applicable every year and there is a need for research to develop a series of options.[10] Much of ATIP's work has recognized this. For example, as will be discussed later, double plowing with broadcasting is advocated, only under certain circumstances, as an alternative to the traditional single plowing and broadcasting system. Also it is important to note that, as farmers move up the technology ladder, the range of options open to the farmer increases. As a result, on occasion it may be appropriate for farmers to simultaneously use, on different parts of the farm, technologies associated with different steps up the technology ladder.

1.3.2 CLIENTS FOR ON-FARM TECHNOLOGICAL RESEARCH

Although, by definition in FSR, it is the farmer who is the primary beneficiary of on-farm research, it is also evident that work can assist on-station researchers to develop technologies that reflect the needs of the farmers. Thus, while the **primary role** of on-farm research is to design and test technologies with farmers to address problems that they have identified, it does have a secondary **supportive role** in helping on-station researchers design new

[10]. As opposed to a standard "package" (see Section 2.4).

potentially relevant technologies.[11]

The impact of on-farm research can be looked at in another way, in terms of **leverage** or **non-leverage interventions**. Leverage interventions -- sometimes called high leverage -- involve introducing changes in an operation or enterprise in a part of the farming system, which is generally a major production constraint (e.g., soil moisture availability), is a major absorber of farm resources, and/or where timing of those resources is restricted. All other things being equal, the adoption of technologies that improve the productivity of such resources are likely to maximize improvement in the productivity of the farming system as a whole. Low or non-leverage interventions, on the other hand, may not have a major impact on the productivity of the farming system as a whole, but may help in improving the productivity of a particular enterprise. Such interventions are likely to be more acceptable to farmers, since their adoption is likely to require relatively small changes in the current system, compared with high leverage interventions, where major changes are often involved if the technology is adopted.

In Botswana, on-farm research has had an impact in both ways.[12] For example:

(a). On-farm research has responded to requests from on-station researchers to evaluate specific technologies at the farm level. This supportive role has generally involved potential low-leverage type interventions arising out of commodity research programs such as crop variety evaluation (e.g, cowpeas, sorghum, groundnuts, etc.), evaluating seed dressing on groundnuts, evaluating whether labor intensive hilling of groundnuts can be avoided, etc. Depending on the requirements of on-station researchers, these types of technologies are sometimes evaluated at the RMFI level (i.e., if some "harder" quantitative data are required), or may be evaluated in the FMFI mode (i.e, where "softer" qualitative/attitudinal data are obtained). These can be done either with individual farmers or offered as options in the research-oriented farmer groups. Within this situation, on-station researchers have a major role in determining the research agenda of on-farm research, with farmers having a secondary role, if they choose to test the technologies offered. The major motivation behind on-station researchers requesting on-farm research evaluation of their proposed technologies is to elicit the opinions of farmers, and to determine the robustness of the technology when implemented and managed by farmers themselves.

(b). On-farm research has also tried to respond to the needs and problems articulated by farmers. This primary role in Botswana's harsh climatic environment, has tended to focus on high-leverage interventions that ensure maximum use of water during the plowing/planting bottleneck period, to improve the degree of stand establishment, and crop survival through drought periods.

1.4 ORGANIZATION OF THE TECHNICAL SUMMARY

The objective of this technical summary of ATIP's work is to present, in a concise form,

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[11]. An alternative way of viewing these roles is as direct (primary) or as indirect (secondary) impacts.

[12]. The primary role of FSR responding to the needs of farmers, in effect, corresponds to what is described elsewhere as "FSR in the small" while the type responding to station-based researchers is more analogous to "FSR with a pre-determined focus" [ATIP EP 86-3].

what research ATIP has undertaken over the years.

Chapter 2 is devoted to a brief discussion of the farmers' environment from both the physical-biological and socio-economic viewpoints. This is followed in Chapter 3 with a discussion on how ATIP has focussed efforts on involving farmers in the research process.

The remaining chapters are devoted to a summary of various research activities, presented on a theme basis. In Chapter 4 system-type technologies are considered, such as those relating to tillage, planting methods and post-establishment practices, and semi-permanent field development. Chapter 5 is devoted to commodity technologies relating to both crops and livestock. With reference to crop: cowpeas, groundnuts, mung beans and intercropping, are considered, while draft animal and small ruminant studies dominate in the livestock sections. No separate section is devoted to sorghum since this crop is already dominant in the cropping patterns of most farmers, and constitutes by far, the most important crop in any trial or study that is not focussed on specific crops like cowpeas and groundnuts. In the theme related chapters, an effort has been made to summarize discussions, within a theme, under a number of sub-headings, namely:

(a). Justification and major objectives.
(b). Major activities, and a list of references for reports on those activities, mainly in table form.
(c). Major results and conclusions.
(d). Recommendations on what should be done in the future.

Because of the amount of work conducted by ATIP over the years it is not possible to give much detail in this summary report. Therefore other papers that ATIP staff have written need to be referred to for detailed information. The tables referred to in (b) above contain information on:

(a). The name of the survey, study or trial.
(b). If they were trials, what type they were (i.e., according to who managed and implemented them).
(c). The size of sample.
(d). References where results are presented.[13]

Sometimes specific trials, studies and surveys are listed more than once in the tables. This is because trials usually contain several treatments, surveys often have multiple objectives, etc. Therefore, on occasion, results may apply to more than one section in the report. This classification is a complex process and therefore may not always be entirely correct and exhaustive in nature. Also, some of the references to particular topics contain the same material, but all are listed in case some are not readily available. In general, the work and results from the 1989-90 season are not considered, as these data are still being analyzed.

There are in addition, five appendices. The contents of these are as follows:

(a). ***Appendix A: Special Studies.*** These are summaries of studies undertaken that were not part of the mainstream research effort and involve extension and policy-related studies.

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[13] Starting in 1985-6 little data were included in the annual reports themselves. Instead detailed results were increasingly presented in other formats such as Progress Reports (PR Series) and Working Papers (WP).

(b). ***Appendix B: List of Promising Guidelines.*** Arising out of work done by ATIP staff -- some in collaboration with others -- have been a number of promising approaches and technologies. In general, however, these could benefit from more extensive testing at the farm-level before being approved for publication as **Extension Bulletins** (in the case of approaches) or **Agrifacts** (in the case of technologies). Therefore, in order to provide easily understood instructions to facilitate further testing, a series of proposed leaflets called **Promising Guidelines** have been prepared. These are given in detail elsewhere [ATIP RP 6]. In the Appendix of this report only a list is provided.

In terms of **technologies**, the guidelines are classified under a number of themes, namely:

i. Soil moisture enhancement (early plowing, contour strip tillage, water conservation terraces).
ii. Planting and weeding (row planting, hand-row planter, Maun cultivator).
iii. Specific crop activities (cowpeas).
iv. Specific livestock activities (lice control in goats and goat kraal construction)

Similarly, **approaches** are also presented under a number of themes, namely:

i. Farmer involvement (extension- and research-oriented farmer groups, farmer training courses, farmer field days and competitions at Agricultural Shows).
ii. Encouraging collaboration (between research and extension and between on-farm and on-station research).
iii. Techniques (estimating goat weight with heart girth measurements, and bloodless castration).

(c). ***Appendix C: List of ATIP Papers.*** This appendix contains a list of all the papers produced by ATIP[14].

(d). ***Appendix D: Other References.*** This appendix contains a list of other references -- not ATIP -- cited in the this report.

(e). ***Appendix E: Acronyms.*** This appendix contains definitions of the acronyms used in the report.

It will probably appear to some that there are specific research topics that perhaps should have been undertaken by ATIP that apparently were not. To others it may appear that the research program has not been as comprehensive or as well rounded as perhaps would have been desirable. However, because of farmers' interest, there has been a consistent theme in the agronomic work, focussed on tillage/planting systems for improved stand establishment and soil moisture conservation for improved crop productivity. Much of the other work in ATIP's research program has evolved in response to requests and opinions of station-based researchers and from farmers. Consequently such a research program may not appear to be particularly comprehensive. A positive spinoff has been that ATIP has not been working in isolation. In fact, nearly all of ATIP's work has been linked with farmers, on-station researchers, extension/development staff and/or occasionally with planning staff.

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[14]. Rather than referring to individual authors in the this technical summary papers written by staff members connected with ATIP are cited by ATIP publication number.

CHAPTER 2: ENVIRONMENT OF FARMER

2.1 INTRODUCTION

2.1.1 JUSTIFICATION

Farmers do not live and work in isolation. They are members of a nation, of a community, and of a family. They live in a particular place defined by a pattern of social, cultural and environmental characteristics. All of these influence the farmers' production systems, and their willingness and ability to make changes in their farming systems.

In order to design useful technologies, perform meaningful on-farm trials, and implement extension and development programs to meet the needs of farmers, it is vital that agricultural researchers - both on-farm and on-station - understand the farmer's environment. There are two basic aspects to this environment, the physical environment which determines what agricultural production is technically possible, and the socio-economic environment which determines what farmers will do or are able to do [ATIP RP 3, pp. 4-6]. Understanding the farming environment is particularly important to farming systems researchers as it provides the setting within which all of their work takes place. ATIP has conducted a number of studies and surveys to better define the physical and socio-economic environment of the limited resource farmer in the areas where the project has been working.

Major aspects of the physical environment include the soils, the topography and the vegetation on the lands where farmers work, and the rainfall and sun, wind, etc., the land receives.

Farmers have limited resources they can invest in farming. These generally consist of land, labor, capital and management. In the case of the limited resource farmer in Botswana, one aspect of the capital resource, their degree of control of traction, is especially important. During drought periods the availability of government programs is also an important factor for farmers.

How the resources are combined by farmers determines the character of cropping and livestock systems. Farming system teams attempt to understand these systems in order to devise interventions which will be meaningful to farmers. How farmers obtain inputs for agriculture and how they use the products of their labor, for home consumption or for sale, are aspects of the farming system which must be understood. Finally, a clear picture of the farming family itself, who the members are, how they interact, and how they choose to use their resources, is fundamental to working within a farming system.

All of these aspects are relevant to understanding the environment of the farmer, and the environment in which farming systems teams must work. These aspects are discussed in this chapter as they have affected the ATIP program.

2.1.2 APPROACH

The ATIP approach to developing an understanding of the farmers' environment took several directions. These have included:

(a). Exploratory and Census Frame Surveys to develop an understanding of the areas, and

to identify representative villages and farmers.

(b). Studies of village physical environments to characterize the soils, topography and vegetation, and to monitor the environment over time, particularly rainfall and temperature.

(c). Multiple Visit Resource Use (MVRU) Surveys conducted over the first three years of the team's operation to develop an in-depth understanding of the farming system then in use.

(d). Baseline Surveys to describe the general farming system in a region, or to determine the basic characteristics of a part of the system, such as cowpea production.

(e). Special one-time surveys and case studies to increase the teams' understanding of specific issues or situations (e.g., a survey to determine the impact of the governmental Accelerated Rainfed Arable Program (ARAP) and Drought Relief programs in the ATIP areas).

(f). On-going monitoring of certain aspects of the system (e.g., cropping patterns, markets, specific farmers' approaches to farming), to identify changes in the system over time.

The following information is based on approximately fifty studies and surveys conducted by ATIP, in order to more accurately understand the farming system in the areas where ATIP was working. A table of the relevant studies and surveys, and where they are cited in the ATIP literature is included for each topic. There is also a listing of generalized observations drawn from the cited literature for each topic.

The discussion is broken down into a number of topics structured as follows:

(a). The physical environment (Section 2.2).
(b). Farming systems (Section 2.3).
(c). Resource use patterns (Section 2.3.2).
(d). The crop sub-system (Section 2.3.3).
(e). The livestock sub-system (Section 2.3.4).
(f). Marketing and prices (Section 2.3.5).
(g). Household circumstances (Section 2.3.6).
(h). Implications for developing relevant technologies and policies (Section 2.4).

2.2 PHYSICAL ENVIRONMENT

A list of ATIP activities relating to soils, rainfall and temperature is given in Table 2.1.

2.2.1 SOILS

Studies on soils, conducted by ATIP, revealed the following information:

(a). Loamy sands to sandy loam soils dominated. Soils were generally deficient in phosphorus, low in organic matter, and had poor water holding capacity [Mays and Price, 1987]. These soils were also assumed to be low in mineral nitrogen. There was a great deal of within field variability.

(b). On-farm research sites ranged from deep soils with high water holding capacity to

TABLE 2.1: ATIP SURVEYS AND STUDIES RELATING TO THE PHYSICAL ENVIRONMENT

MAJOR FOCUS	MORE DETAILS	SURVEY/STUDY	YEAR[a]	AREA	SAMPLE[b]	ATIP PAPERS	
Soils, Vegetation and Topography	Predominate types of soils	Project area description	1985-6	Mahal.	4 villages	RP 1, p.148-154	
		Site characterization study	1986-8	Mahal.	50 fields	WP 15, p.3-4	RD 87-1, p.II.24-26
	Physical characteristics	Soil variability study	1983-5	Mahal.	42 fields	RP 1, p.154-166	
	Site characterization study		1986-8	Mahal.	50 fields	WP 15, p.3-4	RD 88-2, p.40-41
					MP 88-12, p.4		
Rainfall	Annual statistics	Meteorological monitoring	1982-90	Mahal.	Various	RD 84-1, p.1.4	RD 85-1, p.1.5
			1983-90	F'Town	Various	RD 86-1, p.6	RD 87-1, p.I.4
						RD 88-2, p.4	RD 89-2, p.5
	Patterns and planting opportunities	Rainfall/soil moisture study	1985-6	Mahal.	Various	RP 1, p.136-146	WP 15, p.3
						MP 88-8, p.1	EP 89-4, p.172-173
	Meteorological monitoring		1982-90	Mahal.	Various	PR M89-2, p.3	
			1983-90	F'Town	Various	RD 86-1, p.88-89	RD 88-2, p.63-64
					RP 2, p.34-37	RD 89-2, p.87	
					PR F86-1, p.2	PR F87-1, p.2	
					PR F88-2, p.2-3		
Temperature	Patterns	Meteorological monitoring	1982-90	Mahal.	Various	RP 1, p. 147-148	
			1983-90	F'Town	Various	RD 86-1, p.88	RD 87-1, p.II.63
	Soil surface	Meteorological monitoring	1982-90	Mahal.	Various	RP 1, p. 147	WP 15, p.3

a. The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season, and 1984-5 refers to both the 1984-85 and 1985-86 cropping seasons.

b. Refers to the number of sites, farmers, etc. Figures in the column separated by a comma indicate sample sizes in different year.

shallow soils with little capacity. The position on the topographical sequence had an important influence on the characteristics of the soil. At the same time, the sites generally had poor chemical properties. They were low in phosphorous, had low organic matter, a low percent base saturation rate and had variable, and sometimes low, pH. Upland soils showed signs of erosion loss. Old fields, particularly on coarse textured soils, had less top soil than similar fields that had not been cultivated as long. Positions on fields that were at a point where water run-on was received during storms, were often eroded down to the point of the argillic layer.

(c). The study areas generally fell within the hardveld vegetative zones and ranged from the tree savanna zone, dominated by Acacia or Acacia and Combretum species, in the Mahalapye area to mopane bushland in the Francistown area.

2.2.2 RAINFALL AND TEMPERATURES

The following data on rainfall patterns and the effect of rainfall on agricultural activities were observed:

(a) The long-term annual rainfall was 435 millimeters for Mahalapye and 465 millimeters for Francistown. During the 1982-89 project period, the average was 384 millimeters for Mahalapye and 452 millimeters for Francistown (Table 2.2). The rainfall was unimodal, concentrated in November to April. Rainfall was also highly variable between years, within years, and even between fields in the same village. There was no month when the precipitation exceeded the potential evapotranspiration, on a regular basis.

(b). There were times when there were one or more dry periods of at least four weeks duration, long enough to stress plants, during the growing season. Based on a 15 year period, 1970-71/1985-86, in the Francistown area, there was a 94 percent chance of having a dry period[1] of at least four weeks during the cropping season. There was a 38 percent chance of having a dry period of seven or more weeks during the growing season [Unpublished data].

(c). Planting opportunities were dependent on adequate rainfall. The number of rainfall events sufficient for plowing was often limited and sometimes occurred late in the season. That is, they did not occur until late December or early January. This limited the amount of planting farmers could do on "good" soil moisture [ATIP RP 1, pp. 141-147].

(d). Rainfall tended to be concentrated in high intensity rainstorms. Based on a 75 year period in the Mahalapye area, there was an 80 percent chance of having a rainfall event totaling 65 millimeters or more in 24 hours during a season [ATIP MP 87-3]. Because rainfall tended to be unevenly distributed and concentrated in high intensity rain storms, the soil moisture window, suitable for planting activities, was often narrow providing little flexibility in the timing of field operations.

(e). Variation in crop production was primarily a question of the fortunes of rainfall. The growth of planted crops, in the traditional system, was largely determined by the

[1] Defined as having no rain over 1 millimeters on one day or within two consecutive days.

TABLE 2.2: MONTHLY RAINFALL (MMS) AT MAHALAPYE AND FRANCISTOWN, 1982-89[a]

MONTH	MAHALAPYE								FRANCISTOWN							
	30 YEAR AVERAGE	1982 -83	1983 -84	1984 -85	1985 -86	1986 -87	1987 -88	1988 -89	30 YEAR AVERAGE	1982 -83	1983 -84	1984 -85	1985 -86	1986 -87	1987 -88	1988 -89
July	2	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0
August	3	0	1	0	0	0	0	3	1	4	12	0	0	0	0	0
September	10	0	0	5	0	0	6	5	8	0	0	0	0	12	4	0
October	31	85	20	34	44	64	6	43	24	63	89	34	31	66	7	57
November	65	51	99	45	10	62	64	16	62	24	123	76	14	67	54	16
December	77	35	64	30	67	62	149	44	102	39	84	49	49	61	234	76
January	85	49	58	58	7	36	35	83	99	61	5	137	34	68	41	75
February	71	30	13	26	71	15	350	134	84	42	20	134	33	31	254	166
March	54	46	97	45	14	12	91	37	46	42	146	18	59	7	114	8
April	30	22	6	0	59	14	72	52	26	108	17	0	112	0	12	51
May	7	6	1	5	0	0	0	2	11	6	0	0	0	0	0	0
June	1	5	0	0	0	0	0	20	2	0	0	0	0	0	21	0
TOTAL	435	329	361	248	272	266	773	438	465	389	496	448	332	312	741	449

a. The figures for the individual years are the averages for the ATIP villages in each area. The long-term averages are for Mahalapye and Francistown urban areas.

rainfall pattern occurring after planting.

With reference to temperatures, two important points to note were as follows:

(a). The average high was 33°C. during the summer growing period. Soil surface temperatures sometimes reached 60°C., which is above the cardinal temperature for sorghum seedlings [ATIP MP 88-3].

(b). Towards the end the growing season, decreasing temperatures, particularly at nights, were sometimes responsible for inhibiting plant maturation -- for example, sorghum -- even when sufficient soil moisture was available because of late rains.

2.3 FARMING SYSTEMS

2.3.1 INTRODUCTION

The information presented in this section describes the type of farming systems ATIP encountered.

Mixed livestock-crop systems dominated. Small-scale farmers in Botswana have four types of inputs: labor, land, capital and management. They used these inputs in three ways: to produce crops, to keep livestock and to undertake off-farm enterprises such as working in off-farm employment, beer brewing, etc. However, because of the risky nature of rainfed agriculture, farmers generally buffered or cushioned themselves against disaster by emphasizing livestock -- particularly cattle -- production and off-farm jobs. There was also a dependence on government subsidies and drought relief programs which developed during the drought periods.

The following sections summarize various aspects of the farming system.

2.3.2 RESOURCE USE PATTERNS

Studies and surveys relating to resource use patterns are listed in Table 2.3.

Household resources were limited and unequally distributed. Some households had too little labor, while others lacked traction and/or implements, and still others had too little land. Female-headed households and households which did not own traction animals tended to have underdeveloped land resources, low capital assets, and few livestock. Different interventions and extension messages might be needed for households which own traction versus those which have to hire or borrow traction. The latter households cannot realistically be expected to implement timely tillage operations with traditional technology, or to shift to a multiple tillage system.

2.3.2.1 Traction

Major points about traction were as follows:

(a). ***Types And Access.*** Oxen, tractor and donkey traction were used. In 1986-87 in the two ATIP areas, 57 percent of the farmers owned their own traction -- including eight percent who owned tractors -- while 43 percent hired traction. This ownership varied from 27 percent owning traction in the

TABLE 2.3: ATIP SURVEYS AND STUDIES RELATING TO RESOURCE USE PATTERNS

MAJOR FOCUS	MORE DETAILS	SURVEY/STUDY	YEAR[a]	AREA	SAMPLE[b]	ATIP PAPERS	
Traction	Type and source of traction	Draught Arrangement Survey	1983	Mahal.	90 households	RP 1, p.118-127 WP 22	WP 16 MP 89-2
		Crop Management Survey	1983	Mahal.	116 households	RP 1, p.60-61 WP 22	WP 16 PR M84-4
		Cropping Plans Survey	1983	Mahal.	45 households	PR M83-2	
		DUMI[c] Study	1984-5	Mahal.	52 households	RP 1, p.61-64	
		MVRU[d] Survey	1983-5	F'Town	30 farmers	RP 2, p.49-51	
		Ag. Demonstrator Survey	1983	Mahal.	52 ADs	PR M84-2, p.5-10	
		Baseline Survey	1985	F'Town	213 farmers	RP 2, p.49-51 RD 85-1, p. 8.13	WP 3, p.2-6
		Census Frame Survey	1983	F'Town	1367 farmers	PR F85-1	
		Plough Subsidy Study	1985	F'Town	29 farmers	PR F85-5	
		Cooperator Survey	1985-9	F'Town	27 households	PR F87-1, p.8-12	PR F88-2, p.3-4
			1988-9	Mahal.	70 farmers	PR M89-2, p.1-2	
		ARAP/DR Assessment Survey	1986-7	Mahal.	41 households	RD 87-1, p.II.28-29	
		Matsitama/Mokubilo Pilot-Communal Grazing Study	1987	F'Town	307 households	PR F88-3, p.11	
	Uses of traction	Draught Arrangement Survey	1983	Mahal.	90 households	MP 89-2	WP 22
		Crop Management Survey	1983	Mahal.	116 households	WP 22	
		Activity Survey	1984-6	Mahal.	51 households	WP 22	
		Tractor Record Study	1985-	Mahal.	35 tractor owners	RD 86-1, p.50-52	
	Changes in traction use over time	Draught Arrangement Survey	1983	Mahal.	90 households	MP 89-2, p. 3	
		Crop Management Survey	1983	Mahal.	116 households	RP 1, p.61-63	
		DUMI[c] Study	1984-5	Mahal.	52 households	RP 1, p.61-63	
		Cooperator Survey	1985-9	F'Town	27 households	RD 88-2, p.61	RD 89-2, p.83
		ARAP/DR Assessment Survey	1986-7	Mahal.	41 households		
				F'Town	57 households	MP 89-2, p.3 WP 16, p.26-28	
		Secondary Data					
Labor	Agricultural labor patterns	MVRU[d] Survey	1982-4	Mahal.	27 households	RP 1, p.49,72-78,98-101	RD 85-1, p.7.3-7.5
			1983-5	F'Town	30 farmers	RP 2, p.42-48	RD 85-1, p.8.4-8.6
		Crop Management Survey	1983	Mahal.	116 households	PR M84-4	
		Cowpea Baseline Survey	1984	Mahal.	49 households	PR M84-5	
		Baseline Survey	1985	F'Town	213 farmers	WP 3 p.2.13-2.14	
		ARAP/DR Assessment Survey	1986-7	Mahal.	41 households		
				F'Town	57 households	RD 87-1, p.II.29	
		Ploughing Labor Study	1986-9	F'Town	92 observations	PR F87-4	PR F90-10
		Bean Baseline Survey	1989	Mahal.	55 farmers		
				F'Town	89 farmers	WP 24, p.5	
	Non-agricultural labor	MVRU[d] Survey	1982-4	Mahal.	27 households	RP 1, p.94-97	
			1983-5	F'Town	30 farmers	RP 2, p.60-62	RD 85-1, p.8.20-8.22

a.The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season, and 1984-5 refers to both the 1984-85 and 1985-86 cropping seasons. b.Refers to the number of sites, farmers, etc. Figures in the column separated by a comma indicate sample sizes in different years. c. DUMI equals Decision Unit Management Information. d.MVRU equals Multiple Visit Resource Utilization.

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TABLE 2.3: ATIP SURVEYS AND STUDIES RELATING TO RESOURCE USE PATTERNS (CONTINUED)

MAJOR FOCUS	MORE DETAILS	SURVEY/STUDY	YEAR[a]	AREA	SAMPLE[b]	ATIP PAPERS	
Land	Lands area use and improvement patterns	MVRU[c] Survey	1982-4	Mahal.	27 households	RD 84-1, p.7.2-7.4,7.11-7.12	
			1983-5	F'Town	30 farmers	RP 2, p.37-40	RD 85-1, p.8.3-8.4
		Crop Management Survey	1983	Mahal.	116 households	PR M84-4	
		DUMI[d] Study	1984-5	Mahal.	52 households	WP 17, p.10-11	
		Census Frame Survey	1983	F'Town	1367 farmers	RP 2, p.18-22	PR F85-1
		Ag. Demonstrator Survey	1983	Mahal.	52 ADs	PR M84-2, p.5-10	
		Baseline Survey	1985	F'Town	213 farmers	RP 2, p.37-40	WP 3, p.2.1-2.4
		Cooperator Survey	1985-9	F'Town	27 households	PR F87-1, p.3-8	PR F88-2, p.5-7
			1988-9	Mahal.	70 farmers	PR M89-2, p.5	
		ARAP/DR Assessment Survey	1986-7	Mahal.	41 households		
				F'Town	57 households	RD 87-1, p.II.28	
		Matsitama/Mokubilo Pilot-Communal Grazing Study	1987	F'Town	307 households	PR F88-3, p.2-4	
	Changes in land use over time	ARAP/DR Assessment Survey	1986-7	Mahal.	41 households		
				F'Town	57 households	EP 88-4, p.4-5	
Financial Resources	Sources of income and cash flow	MVRU[c] Survey	1982-4	Mahal.	27 households	RP 1, p.94-96,105-111	RD 84-1, p.7.4-7.5
			1983-5	F'Town	30 farmers	RD 85-1, p.8.21-8.22	
		Activity Survey	1984-6	Mahal.	51 households	PR M88-2	
		DUMI[d] Study	1984-5	Mahal.	52 households	WP 17, p.12-14	
		Baseline Survey	1985	F'Town	213 farmers	RP 2, p.60-62	WP 3, p.1.11-1.16
		Ag. Demonstrator Survey	1983	Mahal.	52 ADs	PR M84-2, p.5-10	
		Cattle Post-Lands Study	1986	F'Town	6 farmers		
				Mahal.	15 farmers	WP 7, p.2, 14-15	
	Uses of financial resources	MVRU[c] Survey	1982-4	Mahal.	27 households	RP 1, p.51-57	RD 84-1, p.7.14-7.15
		Activity Survey	1984-6	Mahal.	51 households	PR M88-2	
Government Programs	Participation in government programs (ALDEP, ARAP, DR)	Plough Subsidy Study	1985	F'Town	29 farmers	RP 2, p.52-55	PR F85-5
		Cooperator Survey	1985-9	F'Town	27 households	PR F86-1	PR F87-1, p. 15
						PR F88-2, p.11-13	
		ARAP/DR Assessment Survey	1986-7	Mahal.	41 households		
				F'Town	57 households	RD 87-1, p.II.27-31	EP 88-3
		Matsitama/Mokubilo Pilot-Communal Grazing Study	1987	F'Town	307 households	PR F88-3, p.14	
Equipment	Ownership, use and condition	Draught Arrangement Survey	1983	Mahal.	90 households	MP 89-2	
		Crop Management Survey	1983	Mahal.	116 households	PR M84-4	
		Tractor Record Study	1985	Mahal.	35 tractor owners	RP 86-1, p.50-52	WP 22, p.40-43
		DUMI[d] Study	1984-5	Mahal.	52 households	WP 17, p.8-10	
		Cart Use Survey	1986	Mahal.	30-50 households	WP 22, p.36-39	
		Plough Condition Survey	1984	F'Town	30 farmers	RP 2,p.50-51	EP 86-2, p.263-264
						PR F84-4	
		Baseline Survey	1985	F'Town	213 farmers	WP 3, p.2.5	
		Tractor Costs Survey	1989	Southern	61 farmers	EP 88-3	

a.The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season, and 1984-5 refers to both the 1984-85 and 1985-86 cropping seasons. b.Refers to the number of sites, farmers, etc. Figures in the column separated by a comma indicate sample sizes in different years. c. MVRU equals Multiple Visit Resource Utilization. d.DUMI equals Decision Unit Management Information.

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Mahalapye area to 67 percent owning it in the Francistown area. Roughly fifty percent of the farmers used cattle as their primary draft source -- 15 percent in the Mahalapye area and 75 percent in the Francistown area -- while 17 percent used donkeys. Forty-three percent of the farmers used at least some tractor traction [ATIP RD 87-1, pp. II.27-II.29]. Only about half of the households contro' their own traction, but nearly all had access to traction through custom-hire or, much less frequently, through cooperative arrangements.

(b). *Uses.* The primary use of traction was for plowing. A minority of farmers used traction as a form of transportation, and these farmers used it more frequently for transportation purposes than for plowing. Donkeys were used for transport more often than cattle. Traction animals tended to be undei-utilized during the non-plowing periods.

(c). *Trends.* In the Mahalapye area, more farmers were observed to use donkey traction than at the beginning of the 1980's. More farmers are using hired tractors than before. This trend was developing even before the government introduced subsidies for plowing. In general, there has also been a shift from owned to hired traction due to loss of traction animals, presence of govemment subsidies for plowing, and, because of the out-migration of young people, creating a lack of labor to train and manage animals.

2.3.2.2 Labor

Major points found with respect to labor were as follows:

(a). *Work Allocation.* Not surprisingly, perhaps, crop agriculture did not appear to dominate in the work activities of most households. For example, in 1983-84, in the Mahalapye area, labor use was: 16 percent on fieldwork, 27 percent on livestock tending, 9 percent wage employment, 5 percent on beer brewing, and 42 percent household maintenance [ATIP MP 88-3][2]. In the Francistown area comparable figures for labor use were: 10 percent for arable activities, 26 percent for tending livestock, 7 percent for wage employment, 1 percent for beer making and other household production, and 56 percent for household activities [ATIP RP 2, p. 61]. Of course during high rainfall years the amount of work expended on arable activities -- both in actual and relative terms -- is likely to be higher.

(b). *Gender Composition of Work.* Females in the Mahalapye area accounted for 57 percent of non-cropping labor and 63 percent of fieldwork, but only 16 percent of plowing labor and 21 percent of field maintenance labor [ATIP MP 88-3, p. 3]. Female members of the households in the Francistown area accounted for 43 percent of all arable labor, including 35 percent of the plowing labor (they were involved in plowing 86 percent of the fields), 41 percent of the weeding labor, and 53 percent of the harvesting labor [ATIP RP 2, pp. 42-48].

(c). *Labor Constraints.* It appeared that the critical issue may not have been increasing yield per unit of area, but rather to increase total production through improving the return per unit of labor invested during labor bottleneck periods -- primarily planting. This was because of the nature of the growing season, and also because farming

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[2]. Excluding child rearing and gathering activities.

families were, in general, faced with little labor in relation to land. As a result, very sharp labor shortage bottlenecks occurred for three to five days, following a rain, with reference to plowing/planting operations.

Nearly 75 percent of the potential work force was eliminated due to age -- too young or too old -- school, or wage employment. Only 25 percent of resident members of the households considered arable agriculture as their primary activity. Therefore, labor was sometimes hired to help with plowing, weeding, and harvesting. In 1986-87, 58 percent of the farmers in the Mahalapye area hired some weeding labor while, in the Francistown area, 83 percent hired some weeding labor [ATIP RD 87-1, pp. II.29].

2.3.2.3 Land

Major points with reference to land were as follows:

(a). ***Area Cultivated.*** Generally less than 10 hectares were cultivated per household, with the actual area cultivated depending partly on village and rainfall patterns. Averages varied from around five hectares to almost ten. Also, female-headed households generally cultivated less land than male-headed households simply because they tended to be poorer and therefore lacked resources -- labor, draft and equipment -- to fully cultivate more land.

(b). ***Investment In Land Improvements.*** Farmers used an extensive arable production system. In relation to the resources available to the farm families, the areas cultivated were large. Land was free and available but required an investment in destumping and fencing. In the ARAP-Drought Relief Survey ATIP found that 73 percent of the farmers owned only one field. Fifty-three percent had wire fencing while 16 percent had no fencing. Twenty-six percent had fully destumped fields while 14 percent had not destumped at all. Fifty-nine percent of the farmers in Mahalapye had their primary field destumped, compared to seven percent in the Francistown area [ATIP RD 87-1, pp. II.27-II.29].

There has been a steady amount of destumping under the government subsidy programs. In the Mahalapye area, land clearing has resulted in local shortages of fencing material -- poles and bush -- and firewood. In some villages more than half the farmers had no fencing or only bush fencing. Farmers without wire fencing suffered losses -- ranging from 25 to 100 percent -- due to grazing. There has been a dramatic increase in fencing to protect individual fields in the Mahalapye area, and a substantial increase in the Francistown area. There has also been some development, at the community level, of drift fences to protect the arable fields.

Land improvement measures have tended to concentrate on those designed to improve ease of cultivation and to protect the land from predators. Measures to increase the productivity of the land itself have received little attention. Estimates of soil erosion under native vegetation were relatively low [ATIP MP 88-18]. However when developed for cultivation, land is much more vulnerable to erosion. Developments that occurred above the fields contributed to major flood problems during storms. Protection against erosion generally received little emphasis, while few farmers added kraal manure or systematically incorporated crop residues into the soil.

2.3.2.4 Financial Resources

A few noteworthy points with reference to financial resources were as follows:

(a). *Assets.* An early ATIP study [ATIP RP 1, pp. 55-56] estimated average value of assets for farming families in the Mahalapye area at P10,000. On average, 60 percent of the value of household assets were held in livestock, 30 percent in building, 6 percent in implements and vehicles, and the rest in miscellaneous household goods.

(b). *Cash Income And Cash Flows.* The main cash income source was cattle sales. Off-farm employment, beer brewing and/or remittances were important sources for most households, particularly those without cattle. Crop sales were not important during the existence of ATIP. In most years less than five percent of the areas' households sold crops. In-kind income was obtained from livestock, crop consumption, and gathering. In the Mahalapye area, from November 1983 to June 1984, monthly net cash flows for male-headed households averaged P14.00, while for female-headed households it averaged minus P25.00. This may be attributed to less revenues for female-headed households combined with relatively larger financial commitments in arable agriculture for hiring labor and traction [ATIP MP 89-1].

(c). *Expenditure.* Farming families spent a large share of their money on grain and other food items. Relatively little was expended on inputs or livestock. Of production expenditures, the largest single expense, for those who didn't own traction, was money spent hiring traction or animal draft. It appeared that, for these people, crop production was subsidized by other income sources. For farmers who owned their own traction, there were few expenses unless they hired labor.

2.3.2.5 Government Programs

Almost all farmers in the ATIP areas have participated in the ARAP program, and most of the eligible farmers have participated in the ALDEP program[3]. Women have participated in these programs but have tended to start later than men and have not participated in as many aspects of the programs. As a result of ALDEP there has been some increase in the number of traction-owning farmers beginning to row plant in the Mahalapye area. In general, however, it appeared that government subsidies tended to apply more pressure to increase the area cultivated rather than on intensification measures to increase yield per unit of area.

2.3.2.6 Equipment

The level of capital investment in equipment was extremely low. Households in the Mahalapye area had an average of only P250.00 invested in plows, hand tools, and receptacles. Two possible reasons for this were:

(a). Equipment purchases tended to increase costs and did not provide improved returns every year. The increased risk of a loss associated with investments in new equipment tended to keep farmers from making the investments.

(b). Much equipment was under-utilized during substantial periods of the year.

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[3]. Arable Lands Development Program.

Equipment that did exist tended to be in poor condition, which led to poor plowing and row planting. For example, one study indicated over 80 percent of the farmers owned moldboard plows, but half showed excessive wear and 40 percent could not be adjusted [ATIP PR F84-4][4].

Because of the drought and supportive government plowing subsidy programs during ATIP's existence, there has been an increase in tractor traction. One study [ATIP EP 88-3] estimated that tractors cost P37.00 per hectare to operate, if they plowed an average of 139 hectares per year. Tractors tended to be under-utilized due mainly to frequent breakdowns. The problem arose because of the importation of used tractors, and the lack of trained mechanics and spares.

Carts, used to transport goods, people, firewood and water, tended to be old and in poor condition. The introduction of the cart into the ALDEP program would undoubtedly enable draft animals to be used more frequently throughout the year.

2.3.3 THE CROP SUB-SYSTEM

Studies and surveys relating to the crop sub-system are given in Table 2.4

2.3.3.1 Planting Patterns And Production

Points with reference to planting patterns and production can be summarized as follows:

(a). *Planting Operation*. The distance from the cattle posts to the lands was a major factor influencing decisions on when to start plowing. It directly affected how soon farmers could begin plowing. The traditional single plowing/broadcast system used by 95 percent of the farmers was implemented at any time, beginning in mid-October and going on to the end of February. With animal traction, each hectare took from four to six days to plow. In dry seasons, the number of days appropriate for this operation were limited. The plowing and planting resource was a function of access to traction, labor and equipment plus the number of "plow-planting days" occurring in the season. A range of tillage-planting dates were, in fact, desired. The resulting range in maturity cycles of the crops not only spread out the risk of drought reducing crop production, but also spread out the work load of weeding and harvesting.

(b). *Crops Grown*. Sorghum, grown by more than 90 percent of the farmers, was the main crop produced for home consumption in the Mahalapye area while millet was an important crop, along with sorghum, in the Francistown area. Cowpeas, melons and groundnuts were important intercrops, mainly for home consumption, but with some sales. Although the number of years farmers received a good yield from maize was very low, 45 percent continued to plant some maize every year -- probably because it was immune to bird damage and was a popular food item.

Seed availability played a major role in determining which crop/varieties were planted. Seeds of specialty crops such as cowpeas and groundnuts were often in short supply as were seeds for many local sorghum varieties.

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[4]. Similar, but somewhat less discouraging results have been obtained with respect to row planters -- see Section 4.4.3.1.

TABLE 2.4: ATIP SURVEYS AND STUDIES RELATING TO THE CROP SUB-SYSTEM

MAJOR FOCUS	MORE DETAILS	SURVEY/STUDY	YEAR[a]	AREA	SAMPLE[b]	ATIP PAPERS	
Planting Patterns	Timing of planting	Crop Management Survey	1983	Mahal	116 households	RP 1, p.64-67,28-33	WP 17, p.12-15
		DUMI[c] Study	1984-5	Mahal	52 households	RP 1, p.64-67	
		Ag. Demonstrator Survey	1983	Mahal	52 ADs	PR M84-2, p.14-17	
		Cooperator Survey	1985-9	F'Town	27 households	PR F87-1, p.8	
	Crops planted	MVRU[d] Survey	1982-4	Mahal	27 households	RD 84-1, p.7.17-7.18	
			1983-5	F'Town	30 farmers	RP 2, p.39-42	
		Crop Management Survey	1982	Mahal	116 households	RP 1, p.60-61	WP 17, p.34-38
		Cropping Plans Survey	1983	Mahal.	48 households	PR M84-4	
		Cowpea Baseline Survey	1984	F'Town	275 farmers	PR M83-2	
		Baseline Survey	1985	F'Town	213 farmers	PR F84-1	
		Ag. Demonstrator Survey	1983	Mahal.	52 ADs	RP 2, p.39-42	WP 3, p.2.10-2.11
		Cooperator Survey	1985-9	F'Town	27 households	PR M84-2, p.11-12	
			1988-9	Mahal.	70 farmers	PR F87-1, p.12-19	PR F88-2, p.7
		Matsitama/Mokubilo Pilot-Communal Grazing Study	1987	F'Town	397 households	PR M89-2, p.8-10	
Harvests	Harvested yields	Bean Baseline Survey	1989	Both	144 farmers	PR F88-3, p.11-14	
		Crop Management Survey	1983	Mahal.	116 households	WP 24	
		Cowpea Baseline Survey	1984	Mahal.	49 households	RP 1, p.78-87	
		MVRU[d] Survey	1982-4	Mahal	27 households	PR M84-5	
		Abridged MVRU[d] Survey	1984-5	Mahal.	13 households	RD 84-1, p.7.3-7.4	MP 85-9
		Cooperator Survey	1985-9	F'Town	27 households	RP 1, p.78-87	
			1988-9	Mahal	70 farmers	RD 89-2, p. 83	PR F87-1, p.16-18
	Disposition of harvest	Crop Management Survey	1983	Mahal.	116 households	PR F88-2, p.8-9	
		Cowpea Baseline Survey	1984	Mahal.	49 households	PR M89-2	
				F'Town	275 farmers	RP 1, p.87-88	
		Baseline Survey	1985	F'Town	213 farmers	PR M84-5	
		Cooperator Survey	1985-9	F'Town	27 households	PR F84-1	RD 84-1, p. 8.16-8.17
		Bean Baseline Survey	1989	Both	144 farmers	RP 2, p. 62-63	
						RD 89-2, p.83	
						WP 24, p.7	

a. The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season, and 1984-5 refers to both the 1984-85 and 1985-86 cropping seasons.

b. Refers to the number of sites, farmers, etc. Figures in the column separated by a comma indicate sample sizes in different years.

c. DUMI equals Decision Unit Management Information.

d. MVRU equals Multiple Visit Resource Utilization.

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Date: September 5, 1990

TABLE 2.4: ATIP SURVEYS AND STUDIES RELATING TO THE CROPPING SUB-SYSTEM (CONTINUED)

MAJOR FOCUS	MORE DETAILS	SURVEY/STUDY	YEAR[a]	AREA	SAMPLE[b]	ATIP PAPERS	
Cropping practices	Cropping practices	MVRU[c] Survey	1982-4	Mahal.	27 households	RD 85-1, p.7.5-7.8	
		Crop Management Survey	1983	Mahal.	116 households	RP 1, p.67-72 PR M84-4	WP 16, p.15-16
		Ag. Demonstrator Survey	1983	Mahal.	52 ADs	PR M84-3 MP 85-9	PR M84-2, p.14-20
		Cropping Plans Survey	1983	Mahal.	45 households	PR M83-2	
		Cowpea Baseline Survey	1984	F'Town	275 farmers	RD 84-1, p.8.17-8.18	PR F84-1
				Mahal.	49 households	RD 84-1, p.7.17-7.21	PR M84-5
		DUMI[d] Study	1984-5	Mahal.	52 households	RD 85-1, p.7.24-7.28	
		Baseline Survey	1985	F'Town	213 farmers	WP 3, p.2.11-2.13	RD 85-1, p.8.13-8.16
		Cooperator Survey	1985-9	F'Town	27 households	RD 86-1, p.88-91 RD 88-2, p. 61 PR F87-1, p.14-21	RD 87-1, p.II.63-65 RD 89-2, p. 83-84 PR F88-2, p.7-8
			1988-9	Mahal.	70 farmers	PR M89-2, p.5-10	
		Matsitama/Mokubilo Pilot-Communal Grazing Study	1987	F'Town	307 households	PR F88-3, p.11-14	
		ARAP/DR Assessment Survey	1986-7	Mahal.	41 households		
				F'Town	57 households	RD 87-1, p.II.29	EP 88-4, p.3-4
	Problems with crops	Ag. Demonstrator Survey	1983	Mahal.	52 ADs	PR M84-3	PR M84-2, p.21-24
		Crop Management Survey	1983	Mahal.	116 households	WP 17, p.24-27	PR M84-4
		Cowpea Baseline Survey	1984	Mahal.	49 households	PR M84-5	RD 84-1, p. 7.19-7.20
				F'Town	275 farmers	PR F84-1	
		Baseline Survey	1985	F'Town	213 farmers	RP 2, p.51-52 WP 3, p.2.16-2.19	RD 84-1, p. 8.16
		Cooperator Survey	1985-9	F'Town	27 households	PR F87-1, p.19-21	PR F88-2, p.10
		Matsitama/Mokubilo Pilot-Communal Grazing Study	1987	F'Town	307 households	PR F88-3, p.11-14	
		Bean Baseline Survey	1989	Both	144 farmers	WP 24, p.6-7	

a. The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season, and 1984-5 refers to both the 1984-85 and 1985-86 cropping seasons.
b. Refers to the number of sites, farmers, etc. Figures in the column separated by a comma indicate sample sizes in different years.
c. MVRU equals Multiple Visit Resource Utilization.
d. DUMI equals Decision Unit Management Information.

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(c). ***Production.*** Yields of cereal crops averaged about 200 kilograms per hectare, but during droughts, were often complete failures. Variability in yield resulted not only from problems in establishment, but also from post-establishment factors such as drought periods, weeds (e.g., Cynodon dactylon), insect and quelea bird damage, and livestock and wild animal damage. In the Mahalapye area farmers reported a "normal" sorghum production level of 586 kilograms per family [ATIP WP 17, p. 19]. In the Francistown area, the average for 1983-84 to 1985-86 was 458 kilograms of sorghum and 284 kilograms of millet per family per year [ATIP PR F87-1, p. 17].

2.3.3.2 Cropping Practices

Traditional crop production was a response to the rainfall pattern of the season. Water was generally the limiting factor. The system operated on the basis of accepting the production that rainfall allowed. Purchased inputs were generally very low (e.g., fertilizer, pest control) on a per hectare basis. Other practices such as thinning -- even when needed -- gap-filling, soil building, etc., have not been practiced in the traditional system. Crops were usually planted in mixtures. The traditional, or conventional tillage planting system consisted of broadcast seeding on unprepared land followed immediately by a single plowing operation using a moldboard plow. No chemicals were used. Timing of the tillage planting operation, to take advantage of the available soil moisture, was one of the most important management variables affecting sorghum grain yields. Optimal timing under the traditional system was very difficult to achieve -- because of the lack of resources made available for crop production. Usually this was because the farmers had no resources to commit, but for a few, a conscious decision was made to allocate resources to areas, other than crop production, where investment opportunities were more promising. Therefore the following situations generally arose:

(a). Although most farm families wanted, as much as possible, to produce food for their own consumption needs and to avoid using other income sources for obtaining food, in the majority of cases long-term subsistence was not achieved. This was because farmers were reluctant to make many of the investments that would pay-off under average or good rainfall, due to the risk of drought-related failures. Production inputs were limited and only made as a response to the climatic patterns during the season -- that is, the rainfall pattern. Areas planted and weeded varied from season to season on most farms, and average production remained far below capacity, and below the subsistence objective in most seasons.

(b). Crop plant populations tended to be highly variable. An excess of seed was broadcast. Good soil moisture following planting sometimes resulted in excessive plant populations, but generally, plant populations were below agronomic or economic optima.

(c). The final response to poor rainfall was to abandon the planted crop or not to plant at all. Farmers often delayed weeding during severe drought in order to first determine the likelihood of some production.

(d). The prevailing attitude was that increased production came from planting larger areas and hoping for good rains. Consequently, farmers were attempting to increase the area cultivated. This trend was supported by the government subsidy programs.

However, it was noteworthy that:

(a). Some farmers demonstrated an interest in producing to generate income from at least part of their cropping enterprise. This type of production was often in some form of specialty area such as legume grain or spinach, sweet sorghum stalks, etc. In some cases the value to the producer of this crop was increased by processing -- for example, sorghum beer, cowpea leaf spinach, boiled groundnuts -- or by sale as seed rather than grain. The unit value of such crops increased dramatically when local production of the item was poor.

(b). Although households lacking traction, those headed by females, and those having few or no cattle, nearly always had the lowest levels of crop production, there were some farmers who regularly had greater production. These "intermediate" farmers generally had above average cattle assets, fenced and destumped fields, adequate labor resources, and draft animals.

2.3.4 THE LIVESTOCK SUB-SYSTEM

A list of studies and surveys relating to the livestock sub-system is given in Table 2.5. Major points can be summarized as follows:

(a). *Ownership Patterns.* In 1986-87, 11 percent of the farmers in the ATIP areas did not own cattle[5]. Forty-two percent owned from one to 15 head and 47 percent owned 16 or more head. Thirty-two percent owned an average of 6.5 donkeys [ATIP RD 87-1, p. II.28]. Most households owned smallstock and chickens. Cattle assets were unequally distributed, which contributed substantially to overall inequality since cattle were the main assets of most households. Goats, chickens and donkeys were more equally distributed than were cattle. In addition, livestock inventories fluctuated with the rainfall conditions. During drought periods the goat population tended to increase -- kidding rates of 137 percent were estimated for some years -- while chicken and donkey populations decreased less than for cattle.

(b). *Use of Animal Products.* Eggs and chickens were primarily used for home consumption. The primary use of both cattle and smallstock meat was for sale, often to Botswana Meat Commission (BMC). Approximately twice as many families consumed their own smallstock as consumed their own beef. More than 90 percent of families used milk from smallstock for home consumption, while almost as many families used milk from cattle for home consumption, mostly at the cattle posts. A small number of farmers -- less than 10 percent -- sold milk, but for those who did, it provided a good return, particularly if sold as madila.

One study estimated that income from an average herd of about 25 goats was approximately P425.00 per year. This included the value of milk and meat sold and used by the family [ATIP WP 36].

(c). *Management Practices.* The distance from cattle posts to land areas may have been one factor preventing the early season use of cattle traction teams. Farmers did not

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[5]. The percentage of households owning not cattle was however, much higher in earlier, and probably more representative surveys of the ATIP villages. In 198-32 the corresponding percentages were 44 percent for the Mahalapye area [ATIP RP 1, p.15] and 22 to 30 percent for the villages in the Francistown area [ATIP RP 2, p. 18].

TABLE 2.5. ATIP SURVEYS AND STUDIES RELATING TO THE LIVESTOCK SUB-SYSTEM

MAJOR FOCUS	MORE DETAILS	SURVEY/STUDY	YEAR[a]	AREA	SAMPLE[b]	ATIP PAPERS	
Ownership Patterns	Cattle	Crop Management Survey	1983	Mahal.	116 households	RP 1, p.46-47	
		Livestock Practices Survey	1985	Mahal.	88 households	WP 20, p.3-5	
		Census Frame Survey	1983	F'Town	1367 farmers	RP 2, p.18	PR F85-1
		Baseline Survey	1985	F'Town	213 farmers	WP 3, p.3.1-3.5	
		Livestock Practices Survey	1984	F'Town	42 farmers	PR F84-2	
		ARAP/DR Assessment Survey	1986-7	Both	98 households	RD 87-1, p.II.27-31	
		Matsitama/Mokubilo Pilot-Communal Grazing Study	1987	F'Town	307 households	PR F88-3, p.4-10	
	Smallstock	Census Frame Survey	1983	F'Town	1367 farmers	PR F85-1	
		Livestock Practices Survey	1984	F'Town	42 farmers	EP 86-2, p.262-263	
		Matsitama/Mokubilo Pilot-Communal Grazing Study	1987	F'Town	307 households	PR F88-3, p.4-10	
	Livestock inventories	MVRU[c] Survey	1982-4	Mahal.	27 households	RP 1, p.53-55	RD 84-1, p.7.12-7.14
			1983-5	F'Town	30 farmers	RP 2, p.59-60	RD 85-1, p.8.18-8.20
						PR F85-2	PR F86-1
						PR F87-3	
		Livestock Practices Survey	1985	Mahal.	88 households	RP 1,p.53-55,89-90	WP 20, p.3-11
		Cooperator Survey	1985-9	F'Town	27 households	RD 86-1, p.91-92	RD 87-1, p.II-65
						PR F87-3	
Use of Animal Products	General use (meat, milk, eggs)	Livestock Practices Survey	1985	Mahal.	88 households	RP 1, p.93-94	WP 20
			1984	F'Town	42 farmers	PR F84-2	
		Goat Use Study	1989-90	F'Town	20 farmers	WP 36, p.7	
	Meat	Cattle Post-Lands Study	1986	Both	21 farmers	WP 7, p.14	
		Smallstock and Grain Price	1984-9	F'Town	5 firms	RP 2, p.62-65	RD 86-1, p.92
						RD 87-1, p.II.65	RD 88-2, p.61
		Livestock Practices Survey	1984	F'Town	42 farmers	EP 86-2, p.262-263	
		Matsitama/Mokubilo Pilot-Communal Grazing Study	1987	F'Town	307 households	PR F88-3, p.4-10	
	Milk	Goat Management Study	1986-7	F'Town	20 farmers	MP 86-9	
						PR F87-2	PR F88-1
						MP 88-15	MP 86-5
		Cattle Post-Lands Study	1986	Both	21 farmers	WP 7, p.13	
		Goat Use Study	1989-90	F'Town	20 farmers	WP 36	

a. The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season, and 1984-5 refers to both the 1984-85 and 1985-86 cropping seasons.

b. Refers to the number of sites, farmers, etc. Figures in the column separated by a comma indicate sample sizes in different years.

c. MVRU equals Multiple Visit Resource Utilization.

TABLE 2.5: ATIP SURVEYS AND STUDIES RELATING TO THE LIVESTOCK SUB-SYSTEM (CONTINUED)

MAJOR FOCUS	MORE DETAILS	SURVEY/STUDY	YEAR[a]	AREA	SAMPLE[b]	ATIP PAPERS	
Management Practices	Traction and transport	Baseline Survey	1985	F'Town	213 farmers	WP 3, p.3.14-3.17	
	Cattle	Draught Arrangement Survey	1983	Mahal	90 households	WP 16, p.21-22	
		Livestock Practices Survey	1985	Mahal	88 households	RP 1, p.91-93 WP 20	WP 15, p.11
			1984	F'Town	42 farmers	RD 84-1, p.8.18-8.19 PP F84-2	EP 86-2, p.263
		Census Frame Survey	1983	F'Town	1367 farmers	PR F85-1	
		Baseline Survey	1985	F'Town	213 farmers	RP 2, p.55-57	WP 3, p.3.5-3.10
		Cattle Post-Lands Study	1986	Both	21 farmers	RD 86-1, p.93-95	WP 7
		Matsitama/Mokubilo Pilot-Communal Grazing Study	1987	F'Town	307 households	PR F88-3, p.4-10	
	Smallstock	Livestock Practices Survey	1985	Mahal	88 households	RP 1, p.91-93 PR M87-2	WP 20
			1984	F'Town	42 farmers	RD 84-1, p.8.18-8.19 PR F84-2	EP 86-2, p.263
		Baseline Survey	1985	F'Town	213 farmers	RP 2, p.55-58	WP 3, p.3.10-3.14
		Goat Management Study	1986-7	F'Town	20 farmers	MP 86-9 PR F88-1 MP 88-15	PR F87-2 MP 86-5
		Matsitama/Mokubilo Pilot-Communal Grazing Study	1987	F'Town	307 households	PR F88-3, p.4-10	
		Goat Use Study	1989-90	F'Town	20 farmers	WP 36, p.3-4	
		Chicken Management Study	1987	M & F	?	PR M87-2	
	Labor requirements	MVRU[c] survey	1982-4	Mahal	27 households	RP 1, p.98-101	
			1983-5	F'Town	30 households	RP 2, p.59-60	
		Cattle post-lands study	1986	Both	21 farmers	WP 7, p.6-7	

a. The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season, and 1984-5 refers to both the 1984-85 and 1985-86 cropping seasons.

b. Refers to the number of sites, farmers, etc. Figures in the column separated by a comma indicate sample sizes in different years.

c. MVRU equals Multiple Visit Resource Utilization.

select and train cattle specifically for draft purposes because of the high sale value of cattle. They tended to use young animals and replace them every two to three years when they were ready for marketing. Depending on the ability of the trainer, it took from a day to two weeks each year to train the animals to pull a plow properly. Farmers rarely provided draft animals with supplemental feed, which might have improved their performance. In fact less than five percent of the farmers in the Mahalapye and Francistown area had ever cut and stored crop residues, or planted fodder crops. Less than half of the farmers used their animals to plow for others, whether relatives or on a hire basis.

Men and hired herd boys tended to care for cattle, usually at cattle posts which were sometimes up to 100 kilometers from the lands areas. Most animals were watered every day and kraaled at night. One hundred percent of cattle were reported to be vaccinated, compared to five percent of smallstock. Women and children were usually responsible for the care and herding of smallstock and chickens.

During drought, lack of grazing forced many farmers in the Francistown area to relocate their cattle posts. Fewer farmers in the Mahalapye area were able to relocate resulting in a higher death rate loss, but also some supplemental feeding.

2.3.5 MARKETING AND PRICES

A list of studies and surveys relating to marketing and prices is given in Table 2.6. Major points can be summarized as follows:

(a). ***Marketing Infrastructure.*** Historically, local trade in Botswana has been dominated by exchanges between households. Households exchanged labor, traction, gathered items, and household products on both a cash and barter basis. Formal trade was more limited and involved mostly trade with small general dealers, and occasionally with organizations such as BMC or Botswana Agricultural Markets Board (BAMB). On the other hand, formal trade has been the main source of food and production inputs during ATIP's existence. Most village trade was handled by small general dealers who sold agricultural commodities, including canned and processed food. A few sold fencing materials, traction-drawn equipment, livestock requisites, and seed. Some also bought local crops and livestock.

(b). ***Sales Patterns.*** Over a five year period in the Mahalapye area, 31 percent of the farmers sold crops at least once. In the Francistown area, 21 percent of the families sold animals and crops in the formal marketing sector and 51 percent in the informal sector. Fifty percent of the families sold cattle and only four percent sorghum. The frequency of the sale of cattle and smallstock to BMC depended on the availability of quotas, and whether the animals came from an European Economic Community (EEC) area.

(c). ***Prices.*** Prices for grains in the villages tended to be two or three times the BAMB prices. Cattle prices were more closely tied to the BMC prices and smallstock prices were determined by local trade, ranging from P35.00 to P110.00 per animal. There tended to be a fluctuation in crop prices depending on the time of the sale related to harvest. There was also a fluctuation in cattle prices based on the difference in prices paid by BMC. One of the factors determining price was whether the animals were from an EEC area. Imported maize meal was the least expensive food grain, followed by sorghum meal, wheat flour and rice. Cowpeas and groundnuts were two to four times as expensive as food grains.

TABLE 2.6: ATIP SURVEYS AND STUDIES RELATING TO MARKETING AND PRICES

MAJOR FOCUS	MORE DETAILS	SURVEY/STUDY	YEAR[a]	AREA	SAMPLE[b]	ATIP PAPERS	
Marketing Infrastructure	Input markets	Crop Management Survey	1983	Mahal.	116 households	PR M84-4	
		Cowpea Baseline Survey	1984	Mahal	49 households	RP 1, p.127-134	
		Trader Baseline Survey	1985	Mahal.	163 traders	RP 1, p.127-134 WP 18	RD 85-1, p.7.15-20
		DUMI[c] Study	1984-5	Mahal.	52 households	WP 17, p.14-18	
		ARAP/DR Assessment Sur.	1986-7	Mahal.	41 households		
				F'Town	57 households	EP 88-4, p.7	
	Output markets	Trader Baseline Survey	1985	Mahal.	163 traders	RD 85-1, p.7-15-7.20	
		Tonota Smallstock Study	1985	F'Town	10 members	RP 2, p.66-67 MP 88-10	PR F85-4
Farmer selling patterns	Crops and livestock	Crop Management Survey	1983	Mahal.	116 households	PR M84-4	
		Cowpea Baseline Survey	1984	F'Town	275 farmers	PR F84-1	
		MVRU[d] Survey	1983-5	F'Town	30 farmers	RD 85-1, p.8.22-8.24	
		Baseline Survey	1985	F'Town	213 farmers	RP 2, p.62-67	
		Smallstock & Grain Price	1984-9	F'Town	5 firms	PR F86-1	
		Matsitama/Mokubilo Pilot-Communal Grazing Study	1987	F'Town	307 households	PR F88-3	
		Goat Use Study	1989-90	F'Town	20 farmers	WP 36, p.5	
Price	Crops prices	Smallstock & Grain Price	1984-9	F'Town	5 firms	RD 88-2, p.61-62	RD 89-2, p.84-85
		Res./Prod. Valuation St.	1987	Mahal.		RD 88-2, p.46-47	
	Livestock prices	Smallstock & Grain Price	1984-9	F'Town	5 firms	RP 2, p.64-65 RD 86-1,p.92 PR F86-1 RD 88-2, p.61-62	RD 85-1, p.8.24-8.26 RD 87-1, p.II.65 RD 89-2, p.84-85
		Res./Prod. Valuation St.	1987	Mahal.		RD 88-2, p.46-47	
		Goat Use Study	1989-90	F'Town	20 farmers	WP 36, p.5	

a The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season, and 1984-5 refers to both the 1984-85 and 1985-86 cropping seasons.
b Refers to the number of sites, farmers, etc.
c DUMI equals Decision Unit Management Information.
d MVRU equals Multiple Visit Resource Utilization.

2.3.6 HOUSEHOLD CIRCUMSTANCES

A list of relevant studies and surveys is given in Table 2.7. Major points can be summarized as follows:

(a). ***Household Membership Patterns***. The average household size in the Mahalapye area was around ten people. Twenty percent of the household members were non-resident, having emigrated for employment. Two-thirds of the residents were children [ATIP MP 88-3]. In contrast, the average household size in the Francistown area was 7.7 people, 80 percent of whom participated in agricultural -- crop and/or livestock -- activities. An average of 1.3 persons had wage employment. The mean age of the household head was 56 years [ATIP WP 3, pp. 1.8-1.16]. Approximately one-third of households in the Francistown area were female-headed with another 15 percent de facto female-headed[6]. In the Mahalapye area, approximately one-quarter of the households were headed by females.

(b). ***Gender Issues***. The division of labor was according to gender. Males were responsible for cattle tending, milking, plowing, destumping and fencing. Women were responsible for nearly all other activities, including much of the plowing in the Francistown area, and for smallstock. As a result women worked more hours in crop production than men[7]. The heavy work load of women sometimes resulted in a severe weeding and harvesting labor constraint during seasons of good rainfall. In the Mahalapye area, 78 percent of the female-headed households hired draft while only 41 percent of the male-headed households hired draft [ATIP PR M89-2]. Finally, for many households there were few males available to participate in agricultural activities, and those who were available often concentrated on livestock activities. Consequently much of the burden of arable agriculture shifted to the female and child members of the household.

(c). ***Food Consumption*** Maize meal was the most frequently consumed food, followed by sorghum meal. Bread and vegetable consumption were increasing. There were differences in levels of consumption at different times of the year, and between households. The level of food consumption was related to wealth status, as indicated by the number of cattle owned. Most food consumed, particularly during the drought, was obtained from small general dealers. Melons, some green vegetables, milk -- the main source of protein for many families -- chicken and eggs were the only items consistently obtained from home production. Meat was infrequently consumed and when it was, it was usually obtained from other farmers. Thus household food security was being achieved by purchasing, not producing food. For example, a survey in the Mahalapye area revealed that after the 1988-89 cropping year only 22.5 percent of the farmers were more than 50 percent self-sufficient in cereal grains [ATIP PR M89-2].

(d). ***Decision Making***. Agricultural decisions were generally made by those with most responsibility in the area -- for example, weeding decisions were made by women,

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[6]. That is, there was a male head of household, who was absent, so the resident female head made the agricultural decisions.

[7]. This is certainly true in the Mahalapye area, although in the Francistown area, males worked slightly more hours.

TABLE 2.7: ATIP SURVEYS AND STUDIES RELATING TO HOUSEHOLD CIRCUMSTANCES

MAJOR FOCUS	MORE DETAILS	SURVEY/STUDY	YEAR[a]	AREA	SAMPLE[b]	ATIP PAPERS	
Household Circumstances	Membership - characteristics and patterns	Sample Frame Census	1982	Mahal.	90% villagers	RP 1, p. 14-16	
		MVRU[c] Survey	1982-4	Mahal.	27 households	RP 1, p. 48-51	PR M88-1
		Ag. Demonstrator Survey	1983	Mahal.	52 ADs	PR M84-2	
		Crop Management Survey	1983	Mahal.	116 households	RP 1, p.14-16	PR M84-4
		DUMI[d] Study	1984-5	Mahal.	52 households	RP 1, p.14-16	WP 17, p.4-6
		Census Frame Survey	1983	F'Town	1367 farmers	RD 84-1, p.8.5-8.7	PR F85-1
		Baseline Survey	1985	F'Town	213 farmers	WP 3, p.1.10-1.11	
		Matsitama/Mokubilo Pilot-Communal Grazing Study	1987	F'Town	307 households	PR F88-3, p.1-2	
		Cooperator Survey	1988-9	Mahal.	70 farmers	PR M89-2	
	Gender issues	MVRU[c] Survey	1982-4	Mahal.	27 households	PR M87-1	MP 89-1
			1983-5	F'Town	30 farmers	MP 89-1	
		Activity Survey	1984-6	Mahal.	51 households	PR M87-1	
		DUMI[d] Study	1984-5	Mahal.	52 households	PR M87-1	
		Baseline Survey	1985	F'Town	213 farmers	WP 3, p.1.8-1.10	
		Cooperator Survey	1988-9	Mahal.	70 farmers	PR M89-2	
		Research Farmer Groups	1986-90	Mahal.	Various	MP 88-3	
	Food consumption issues	Crop Management Survey	1983	Mahal.	116 households	RP 1, p.103-106 RD 87-2, p.20 MP 87-16	WP 19 WP 17, p.19-23
		Cowpea Baseline Survey	1984	Mahal.	49 households	RP 1, p.103-106 PR M84-5	MP 87-16
		Activity Survey	1984-6	Mahal.	51 households	RP 1, p.103-106 MP 87-16 PR M88-2, p.3-4	RD 85-1, p.7.10-12
	Decision Making	DUMI[d] Study	1984-5	Mahal.	52 households	RD 87-2, p.20	PR M85-2

a. The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season, and 1984-5 refers to both the 1984-85 and 1985-86 cropping seasons.
b. Refers to the number of sites, farmers, etc.
c. MVRU equals Multiple Visit Resource Utilization.
d. DUMI equals Decision Unit Management Information.

but in consultation with other family members. The impact of technologies on different members within the household was a complex issue which affected the adoption of new technologies. Customarily adults were expected to look after their parents, children and siblings. Parents had a right to direct their children to do certain things. Authority and responsibility were shared between husband and wife in decisions affecting the welfare of the family. Finally, there was an intricate pattern of inter-household resource sharing for traction/plowing which could be destabilized with negative social effects when new technologies involving increased use of traction were introduced. Farmers sometimes placed more emphasis on social obligations than on economic improvement.

2.4 IMPLICATIONS FOR DEVELOPING RELEVANT TECHNOLOGIES AND POLICIES

2.4.1 BACKGROUND

Material already presented in this report[*] raises a number of issues that have implications for developing relevant improved technologies and policy support systems. A few major points that provide the foundation for the discussion in this section are as follows:

(a). Little in the way of improved technologies has been adopted by the limited resource farmers, and hence the productivity of their farming systems is low. Their farming systems reflect a land extensive system of agriculture rather than a move toward a more land intensive system required for the adoption of most of the improved technologies that are available.

(b). There is considerable heterogeneity in the technical and human environments resulting in differences in the way individual farming families respond to changes and the farming systems they practice. For example, all farmers in a specific area face the same variations in the rainfall, but the way they can and will respond will depend on a large number of factors, such as the topography and soil type(s) on their fields, the technologies and enterprises they currently practice, and the resources -- quality and quantities of labor, land, capital and managerial expertise -- they have at their disposal.

(c). Because of the overriding constraint of water availability, initial steps up the technology ladder are likely to be difficult because they involve major changes on the part of the farmers. Related to the technology ladder problem are two issues complicating the lives and work of not only farmers but also that of research, policy/development and extension staff. These are that, because of the harshness and variability -- inter- and intra-annual -- in the climatic environment, progress up the technology ladder is likely to come about through technologies that break constraints rather than exploit the flexibility within the farming system, and that incorporate contingency planning, that is, allow the farmer to respond to the constraints and opportunities that emerge as the season unfolds.

(d). Because of the risks involved in crop agriculture, and its seasonality, farmers not only grow crops but also, whenever they can, keep livestock and engage in off-farm enterprises. In fact, for most limited resource farmers their aim is likely to be one of engaging in crop agriculture to the extent necessary to provide their food needs,

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*. For example, see Sections 1.3, 2.2 and 2.3.

and to obtain their main sources of cash income from livestock and off-farm enterprises.

These points provide the foundation for the following discussion on implications for developing relevant improved technologies and support systems. For clarity in presentation the discussion is structured as follows:

(a). Relevant evaluation criteria (Section 2.4.2).
(b). Conditional and targeting information (Section 2.4.3).
(c). Subsidies (Section 2.4.4).
(d). Sustainability of production (Section 2.4.5).

The first two topics have particular relevance to developing improved technologies, while the last two are more directed to the appropriate policy/support system.

2.4.2 RELEVANT EVALUATION CRITERIA

It is important to evaluate improved technologies in terms of criteria that are relevant to farmers. Details concerning this are discussed elsewhere [ATIP RP 3, pp. 241-270]. Rather than repeat that discussion here, attention is briefly focussed on two points that arise out of the discussion earlier in this report, that have major implications in terms of evaluating technologies that are discussed in Chapters 4 and 5. These are as follows:

(a). On experiment stations, evaluation of technologies has been primarily expressed in terms of the return per unit of land. However, for most farmers in Botswana, labor has been more limiting than land. The critical labor bottleneck periods resulting from the pattern of rainfall, means that improved technologies, in order to be attractive, must increase the return per unit of labor expended at that time. Increasing the return per unit of land does not necessarily simultaneously increase the return per unit of labor. It is therefore important to evaluate improved technologies not only in terms of return per unit of area, but also in terms of return per unit of labor -- particularly at critical labor bottleneck periods. At the same time it is important to emphasize that because of the overriding limitation of water, the route to improvements in agricultural productivity are likely to involve land intensification in order to efficiently use the limited amounts of water.

(b). Increasing crop productivity through a route that does not decrease risk, and at the same time involves commitment of more resources -- particularly at critical bottleneck periods -- are not likely to be very attractive. Given the realities of the technical and human environment within which the limited resource farmer operates, technologies that improve the level and stability of production, and/or do not require substantial increases in resource outlays, are likely to be most attractive to them. This concern for maintaining low investment has led to ATIP's involvement in system-wide research investigating better water management techniques (see Chapter 4). To come up with improved technologies that require very little investment over and above what is currently being invested, is obviously very difficult to achieve. Having said this, it should be noted that if the opportunity cost of such resources could be lowered, then farmers might be more interested in increasing resource outlays. Obvious examples would include; input subsidization to decrease the financial outlays required, use of labor and draft in non-peak periods etc.

2.4.3 CONDITIONAL AND TARGETING INFORMATION

Because of the heterogeneous environment within which farmers operate, the monolithic technological packages that are often developed make little sense. It is therefore likely that where technological packages have been disseminated, many farmers will adopt 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 limited research resources can be improved by:

(a). Incorporating **conditional clauses**, which would 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 would be 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, and farmers with a specific resource base.

Thus in recognizing the diversity of farmers, farming systems research can help in developing targeted and conditional clauses for proposed improved technologies. In doing so, it can potentially improve the multiplier effect of the limited research resources by providing technologies appropriate to more farmers through widening intervention possibilities. It is particularly important to develop a range of options in the more marginal farming areas. In a sense, such guidelines indicate how more farmers can approach the optimal situation.

In the case of the technologies discussed in Chapters 4 and 5, there is good deal of discussion on issues that have conditional and targeting elements.

2.4.4 SUBSIDIES

The following discussion is not directed at the issue of whether subsidization of agriculture is desirable, in relation to other uses of such funds, to create the new food security policy both at the household and national level. Such a discussion is outside the boundary of this report. Rather the point is to examine, given the current emphasis on subsidies, what would be the best way of using them in the light of the discussion earlier in this report.

The issue is whether it would be better to provide higher product prices or input subsidization or some combination of the two. Botswana may be one of the countries where input subsidization may be a better alternative to product pricing incentives.

There are a number of reasons why increasing the price of a staple food crop might not be desirable:

(a). Botswana is a member of the Southern African Customs Union and, as such, an increase in the price of agricultural products would probably encourage smuggling of products from other countries.

(b). It is unlikely that many limited resource farmers would respond to increasing product

prices. The issue for many of them is being able to grow a crop, rather than one of making decisions on how much to produce. Also there are hidden costs of marketing [ATIP MP 84-8].

(c). The majority of limited resource farmers are net purchasers rather than net sellers of food products. Therefore, for them the cost of living would increase since they do not benefit from selling a staple food crop.

Obviously for large commercial farmers points (b) and (c) have less relevance, but if the main focus is to be limited resource farmers, these are important.

There are a number of other major advantages in using a strategy of input subsidization -- if these inputs are ones that have to be used in agricultural production. They are as follows:

(a). Because of the hostile environment for growing crops, it is unlikely that any surplus funds that limited resource farmers have for investment will go into arable production, since the level and certainty of the return is likely to be better from investing in livestock or off-farm enterprises. Consequently, if certain types of improved technologies, which require substantial financial outlays, are to be adopted, it is likely that much better adoption will be achieved through heavy subsidization. As mentioned above, to develop with improved technologies that require little investment over and above what is currently being put in, will be very difficult to achieve.

(b). Unlike product price incentives, input subsidization does not have to be product specific, leaving the farmer to choose between the production of different products. Much of the subsidization that currently occurs in Botswana is not likely to be product specific, e.g., subsidization of equipment and animals, perhaps subsidization of certain operations, etc.

(c). Input subsidies, can, in a sense, be targeted more easily (e.g., to limited resource farmers) than product price incentives.

Consequently, if agriculture is to be supported in some way, a more rational strategy, in the Botswana setting, would be to use an input subsidization approach rather than a product pricing incentive.

2.4.5 SUSTAINABILITY OF PRODUCTION

What is done now by the current generation of farmers has a bearing on what is potentially possible in the future. Recognition of the negative impact of the environmental degradation on the potential standard of living of future farming families, and possibly society as a whole, has been one of the stimuli behind the National Conservation Strategy (NCS).

Because of low production and the high demand for agricultural products, tremendous pressure has been placed on the agricultural sector, in recent years, to increase production. However, current adoption of technologies and implementation of support programs can have negative or positive influences on environmental stability. Both technologies and policy support systems need to be designed now which will have a positive impact on environmental stability in the future. In essence, policy/support systems are needed which 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 have provided incentives for destumping. This could have negative impacts on

encouraging erosion, thus lowering the potential of the land in the future. A constructive policy is to encourage destumping along with a program to encourage the planting of windbreaks, living hedges, etc. It is essential to bring about convergence between private short-run interests of farmers concerned with maintaining an adequate standard of living and the long-run societal interest in maintaining the environment for future generations.

The closer farmers are to the subsistence levels, the more concerned they are about survival until next year, and the 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, if they are 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 people responsible for developing technologies and policy support programs take conservation into consideration.

2.4.6 CONCLUDING COMMENTS

It is obvious from the above discussion, that the challenges in creating suitable improved technologies, and conditions for their adoption, are great. Although researchers have prime responsibility in developing relevant improved technologies, it is the policy/support system in which the planning, development and extension staff operate, that is important in creating an environment in which farmers can profitably adopt the technologies.

A recent study [ATIP WP 34], 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 their crop land was devoted to the new technologies. Overall, however, the adoption or acceptability index ranged from 0.1 to 26 percent depending on the technology and resource levels of the farmers involved [ATIP WP 34, pp.1, 13].[9],[10]

This highlights the need for close relationships with farmers to ascertain if there are problems with the technology itself. It also serves to emphasize the fact that because many of the technologies involve large changes by farmers, acquisition of extra skills, and new inputs, little spontaneous adoption can be expected to take place in the absence of adequate support systems such as an input distribution system, adequate training possibilities -- extension staff, farmer groups and farmer training programs -- and maybe subsidies to reduce input costs and encourage adoption.

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[9]. The value of the index can range from 0 to 100.

[10]. These data dealt with researcher-oriented farmer groups testing a wide range of experimental technologies, and was not the result of an extension effort.

CHAPTER 3: INVOLVING THE FARMER IN THE RESEARCH AND EXTENSION PROCESS

3.1 INTRODUCTION

As has been repeatedly emphasized in the first two chapters, farmer participation is the cornerstone of FSR activities. Table 3.1 gives a list of studies and surveys relating to the general issue of farmer participation in the work of ATIP. This chapter deals with more specific issues of how ATIP has tried to maximize the effective participation of the farmer in the research and extension process. To illustrate this a number of specific strategies that ATIP has developed and used over the years, are discussed in the following sections. They include:

(a). Farmer evaluation of RMRI trials (Section 3.2.1).
(b). Research-oriented farmer groups (Section 3.2.2).
(c). Extension-oriented farmer groups (Section 3.2.3).
(d). Farmer training (Section 3.3).
(e). Farmer field days (Section 3.4).
(f). Competitions at Agricultural Shows (Section 3.5).

3.2 FARMER PARTICIPATORY RESEARCH

3.2.1 FARMER EVALUATION OF RMRI TRIALS

3.2.1.1 Justification

Farmer participation is a key element of the farmer testing (RMFI or FMFI) research format. It is usually assumed, however, that farmers will not be involved in researcher implemented trials except to observe the trial outcome as a demonstration.

ATIP has sought ways to increase the level of farmer participation in researcher implemented trials. Farmer participation at this level was desirable because it could help to accelerate the screening of treatments and to help make appropriate modifications to the design of the treatments, even before these were put forward for farmer testing.

From ATIP experience, it was clear that not all trials lent themselves readily to farmer assessment. For example:

(a). RMRI trials that included a large number of treatments and, more importantly, interactions between levels of factors, posed problems for farmer assessment. In this instance, the assessment problem was a function of the complexity of the trial design.

(b). Farmer assessment of trials also became complicated when non-treatment variables were held at levels that farmers normally wouldn't use in the management of their own operations. These trial management factors may have been the cause of

TABLE 3.1: ATIP SURVEYS AND STUDIES RELATING TO FARMER PARTICIPATION[a]

MAJOR FOCUS	MORE DETAILS	SURVEY/STUDY	YEAR[b]	AREA	SAMPLE[c]	ATIP PAPERS	
Selection of Study Area		Exploratory Survey	1982	Mahal	50 farmers	RP 1, p. 12-14	MP 85-13, p.9
			1983-4	F'Town	13 officials	RD 84-1, p.8.2-8.5	PR F83-1
RMFI Trial Participants	Selection	Sample Frame Census	1982	Mahal	600 villagers	RP 1, p. 14-19 MP 85-13	RD 83-1, p.V.13-15
		Census Frame Survey	1983	F'Town	1367 farmers	PR F83-1	PR F85-1
		Trial Participation Study	1982-7	Mahal	403 trials	WP 12	
	Patterns of participation	Ag. Demonstrator Survey	1983	Mahal	52 ADs	MP 85-13	
		Crop Management Survey	1983	Mahal	116 households	RP 1, p.19-21	
		Census Frame Survey	1983	F'Town	1367 farmers	RP 2, p.18-21 PR F83-1, p.5-7	RD 84-1, p.8.5-8.7 PR F85-1
		Trial Participation Study	1982-7	Mahal	403 trials	WP 12	
FMFI Farmer Group Participants	Participation	Research Farmer Groups	1985-90	F'Town	Various	RD 87-1, p.II.75-78 RD 89-2, p.89	RD 88-2, p.66-67
			1986-90	Mahal	Various	RD 87-1, p.II.51-53	RD 89-2, p.64-65
	Adoption	Cooperator Survey	1988-9	Mahal	70 farmers	PR M89 2, p.14-15	
		Adoption Study See also Table 3.2	1989	F'Town	158 farmers	WP 34	RD 89-2, p.90

a. Because there are few analytical ATIP references on farming training courses, farmer field days and competitions at Agricultural Shows, these are given in the discussion in the different sections.

b. The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season, and 1984-5 refers to both the 1984-85 and 1985-86 cropping seasons.

c. Refers to the number of sites, farmers, etc.

exceptional outcomes[1], but were hidden to farmers assessing the trial.

In contrast, farmer assessment in the RMRI Rainfall Run-off Management Study[2] has been useful. The trial in this study had only a few treatments, large plots that corresponded to typical farmer plowing acres, and essentially no nidden or atypical trial management factors.

3.2.1.2 Approach

In the farmer evaluation of RMRI work, information was obtained in several areas. Generally ATIP employed researchers from the Rural Sociology Unit (RSU) in the Division of Planning and Statistics (DPS) to assist with the collection of the following types of information:

(a). Conceptually, did the technology appear to have merit in this farming system?
(b). Did farmers have ideas about solutions to problems with the technology that were raised by researchers?
(c). Could farmers identify other problem areas with the technology and possible solutions to these problems?
(d). Could the farmer recommend ways to implement or enumerate requirements for the successful implementation of, this technology?
(e). Could the farmer suggest target situations or households for this technology?

The procedure for obtaining farmer assessment of researcher implemented trials involved:

(a). The purposive selection of farmers with a strong interest in the enterprise to which the new technology related (e.g., arable farmers growing maize), and a selection of farmers representing what were thought to be relevant resource categories.

(b). Organizing at the trial site, a brief -- usually one-half day -- workshop in which researchers, and some farmers, were permitted to present treatments and ideas to participants. Following the presentation of a particular idea, someone led a discussion among the farmers. During the workshop, a type of group interview occurred from which researchers recorded comments. The agenda for the workshop was not fixed and new ideas could be readily added.

(c). Following the group workshop, researchers convened to prepare a short questionnaire which was administered individually to all farmer participants.

(d.) Researchers evaluated responses from both the group discussion and the individual questionnaire responses, and drew conclusions about the technology.

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[1]. Hidden trial management factors included such things as plant stand thinning, basal application of fertilizer and so forth, that would not be typical of practices in the farming community, but were applied in a trial to all treatments. When these types of practices were included, treatment comparisons were still valid, but the ability of many farmers to relate to the outcomes of the trials was impeded.

[2]. Some treatments in this trial are discussed in Section 4.5.1. A description of this trial is available in ATIP RD 89-2, pages 54-56.

3.2.1.3 Results And Conclusions

Farmers were asked to assist formally in the evaluation of RMRI trials in four different years. The evaluation for two years of treatments in the Commercial Steps in Technology Trial [ATIP RD 85-1, pp. 7.26-7.30; ATIP RD 87-1, pp. II.37-II.39] was not highly successful. This trial consisted of multi-year testing of several standard tillage and planting and fertilizer treatments. The evaluation process was largely viewed as a demonstration exercise by the farmers. Groups of farmers were also asked to evaluate two years of the Rainfall Run-off Management Work [ATIP RD 88-2, pp. 41-43; ATIP RD 89-2, pp. 54-56]. This evaluation was more successful because treatments could be readily modified according to suggestions made by farmers.

3.2.1.4 Recommendations

Recommendations for future work entail the following:

(a). Farmer participation in the evaluation of RMRI trials should continue on appropriate research work where farmers can make a contribution.

(b). This type of assessment requires relatively small groups of farmers. Small groups work more efficiently in generating discussion and presenting opinions.

(c). It is suggested that the assistance of individuals with experience in researching issues with farmers be requested in order to provide a more effective interaction with the working group of farmers.

3.2.2 RESEARCH-ORIENTED FARMER GROUPS (ROFG)[3]

3.2.2.1 Justification

The importance of farmer participation in research activities is increasingly being recognized. Since farmers are the end users of research results, their participation during the technology development process can help to ensure that the technology options produced are relevant, effective and practical under real-farm conditions.

During the first three years of on-farm research in the ATIP project, the majority of research was performed under researcher management (RM), with either researcher or farmer implementation (RI or FI respectively). However, FMFI trials work has been expanded through the life of the project.[4] FM work provided the following advantages:

(a). It increased the number of technologies that could be examined because each additional trial required only minimal additional attention from researchers.

(b). It allowed for greater farmer participation in the research process because farmers could participate in the selection of technologies for testing, in the designing of the trials and in the evaluation of the results.

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[3]. At different times during the life of ATIP these have been called Options Testing Groups, Farmer Assessment Groups, and Researcher-Led Farmer Groups.

[4]. See Section 1.2 for a more detailed discussion of trial formats.

(c). The FMFI mode allowed for the performance of technologies to be assessed under farmer managed (FM) conditions.[5]

To facilitate the use of the FMFI mode, the ATIP program began working with groups of farmers. Originally the objectives were to develop efficient systems for handling FMFI trials, and to increase farmer participation in the research process. Several different group formats were tried. These groups met the above objectives, but were seen to have potential for even more activities. Thus the approach was modified and expanded over the years. Even after four seasons of development, the groups operated somewhat differently in the Mahalapye and Francistown regions, due to differences in both farmer and researcher interests. However, in this section, any groups formed for the purpose of conducting research on new technologies and involving primarily FMFI trials work, are referred to as Research-Oriented Farmer Groups (ROFG).

The objectives of the ROFG work included:

(a). To expand the range of technologies examined in the on-farm research program.

(b). To provide a forum for more direct input into the technology development process by both farmers and extension personnel.

(c). To examine the performance of different technologies under farmer management, and to determine what types of innovations were most appealing to farmers of different resource levels.

3.2.2.2 Approach

ATIP used various types of ROFGs in the past, and the different formats have been described in publications listed in Table 3.2. Also, in the past, various names have been used for the same or different farmer groups and activities. Here, this diverse work is consolidated under the term ROFGs. The ROFGs most extensively used in the ATIP work had the following characteristics:

(a). Open participation, and self-selection by farmers.

(b). Individual farmers decided which technologies they would test, choosing them from a range of options.

(c). Trials were managed and implemented by individual farmers.

(d). For each type of trial, farmers and researchers mutually agreed upon a standardized format (e.g., farmers performing a cowpea variety trial would compare the same varieties, all planted with the same seeding rate, on the same size of plot, on the same day, etc.)

(e). Regular group meetings were held throughout the cropping season to discuss progress, farmer observations and evaluations of technologies, and problems arising.

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[5]. There is normally a drop in the performance of technologies when they are moved from RM to FM, but the extent of the drop can only be assessed under real farmer management.

TABLE 3.2: ATIP PAPERS PROVIDING INFORMATION ON FARMER GROUPS

TYPE OF GROUP	ATIP PAPER	PAGES	EMPHP	MAJOR FOCUS
General:	WP 13	All	Desc.	Types and participation in non-ATIP groups
	EP 88-2; EP 89-6			
	EP 89-8; MP 88-5	All	Meth.	Purpose and approaches for research and extension groups
	MP 87-4	All	Meth.	Types, advantages and disadvantages of ATIP groups
	EP 88-5; MP 88-7			
	MP 88-11	All	Desc.	Approach and technologies in both types of groups
	MP 89-6	All	Meth	Sustainability of the ATIP farmer group approach
Research Oriented:	EP 87-2; MP 88-1	All	Meth.	Linking farmers, research and extension
	MP 88-3	All	Desc	Women in groups, management and content of trials
	MP 88-16	All	Meth	Approach used in research-oriented groups
	RD 86-1	52-84 105-109	Desc.	Approach and summary of results for 1985
	RD 87-1	11-74-78	Emp	Approach and summary of results for 1986
	PR F86-2	All	Emp.	1986 double plowing/broadcasting tests with groups
	PR F87-6	All	Emp	1987 results with different technologies
	RD 88-2	63-67	Emp	Approach and summary of results for 1987
	PR F90-2	All	Emp	1988 results with different technologies
	RD 89-2	88-90	Emp	Approach and summary of results for 1988
	PR F90-6	All	Emp	1989 results with different technologies
	WP 11	All	Desc	External evaluation of farmer perceptions of groups
	MP 88-1	All	Meth	Describes different aspects of group methodology
	WP 34	All	Emp	Adoption study with research group participants
Extension Oriented:	WP 25	All	Meth.	Implementing and running groups
	RD 88-2	67-68	Desc.	Approach and summary of results for 1987
	RD 89-2	84-86	Emp	Approach and summary of results for 1988
	PR F90-1	All	Emp.	1987 End-Of-Season Survey results
	PR F90-5	All	Emp.	1988 End-Of-Season Survey results

a. This column indicates the emphasis in the paper cited, namely:
"Meth" refers to the material being primarily methodological,
"Desc" indicates that it contains descriptive material on both methodological and empirical aspects,
"Emp" indicates contents are primarily empirical in nature.

(f). For analysis purposes, researchers checked that the trials had been implemented according to mutually agreed upon guidelines, and recorded the dates of field operations and plot grain yields.

(g). Farmer field days were held in one or more village locations when crops were nearing harvest.

(h). End-Of-Season Surveys were conducted with all participating farmers to quantify farmer evaluations of the various technology options each had examined.

3.2.2.3 Results And Conclusions

An example of the amount of work conducted through ROFGs is provided in Table 3.3. The table presents data on the ROFG activities in Francistown. The types of technologies tested included: crop variety options, crop husbandry options, tillage options, and various equipment options. Details of the technologies tested, yield results and general conclusions can be found in the ATIP Progress Reports for each year. These are listed in Table 3.2.

TABLE 3.3: NUMBER OF VILLAGES, FARMER PARTICIPANTS, TRIALS CONDUCTED AND TECHNOLOGIES TESTED IN ROFG ACTIVITIES, FRANCISTOWN, 1985-89

YEAR	NO. OF VILLAGES	TOTAL FARMER PARTICIPANTS	NO. OF TRIALS[a]	NO. OF TECHNOLOGIES TESTED
1985-86	1	12	1	1
1986-87	3	97	142	9
1987-88	3	143	152	7
1988-89	3	128	140	9

a. Represents the number of trials used.

In ROFGs a number of linkages were established. Three of them are as follows:

(a). ***With Farmers.*** Within the ROFGs, researchers met regularly with groups of 10 to 30 farmers -- as many as three groups per month -- to discuss farmers' activities, their observations on the various technologies, problems arising, and the general field situation. Thus the ROFGs provided an important channel of communication between research and the farming community. In addition, the End-Of-Season Survey served to quantify farmers' opinions and perceptions in each year, and created a permanent record over the years.

Since the farmers decided which technologies were tested, and because their evaluations were the primary topic in the discussion sessions and the End-Of-Season Survey, the ROFG approach allowed farmers a strong voice in the technology evolution process.

(b). ***With Extension Personnel.*** Over the years, local ADs were invited to attend all ROFG monthly discussion sessions, and all other activities, and therefore had the opportunity to participate in the technology evolution process. In addition, extension personnel at the district and regional levels participated in the field day activities and so were continuously aware of new developing technologies.

(c). ***With On-station Commodity Research Teams.*** The ROFG format made it relatively easy to add new technologies to the farmer testing program. Thus the ROFG enabled the on-farm research programs to respond rapidly to the needs of on-station commodity research programs for FMFI testing of technologies they developed. This led to increased collaboration between FSR teams and station-based researchers. During the last three years of the project, the ROFG format was used for collaborative research with a number of station-based research programs.[6] Examples included:

i. Crop Improvement:

Sorghum and millet	-- new varieties
Cowpea	-- new varieties
Groundnut	-- new variety
	-- seed dressing
	-- hilling versus not hilling
	-- new planter

6. In addition, the ROFG produced information relevant for both the Soil and Water Management Group and soil fertility scientists at Sebele.

ii. Weed Agronomy -- Dutch hoe

iii. Farm Machinery Development Unit -- hand row planter
-- light weight cultivator (Maun)
-- tractor mounted plow planter

The major conclusions derived from work with ROFGs were as follows:

(a). The regular monthly meetings between farmers, researchers and extension personnel ensured that both research and extension were constantly aware of the field situation, and that farmers' problems, interests, and perceptions were well understood. Simultaneously, they were a good forum for collaboration between research and extension.

(b). The ROFG format was a practical and effective method for incorporating farmers into the technology development process.

(c). Using the ROFG approach could help to ensure that the technologies coming out of the research system are both practical and effective, even under farmers' resource constraints.

(d). The ROFGs were an effective tool for increasing the scope of the on-farm research programs.

(e). Use of the ROFGs encouraged more collaborative work between on-station and on-farm research programs because of the ease with which new technologies could be added to the farmer testing activities. At the same time, the ROFGs made it easier for on-farm research programs to respond to farmers needs and interests.

The ROFG approach has been found to be an extremely useful tool, which might be of benefit to other on-farm research programs now operating in Botswana. However, it must be noted that the ROFG approach is still developing, and there are some issues which have yet to be resolved.[7] In addition, it is not a rigid system. The approach will be most successful where it is adapted to fit local objectives, and local farmer interests.

3.2.2.4 Recommendations

The following actions, in addition to the **Promising Guideline** which has been prepared [ATIP RP 6, Section 3.2.1], are recommended with respect to ROFGs:

(a). Work with ROFGs should be continued in those villages where they are operating at present, so that farmers do not get discouraged about a reduction in commitment.

(b). ATIP staff experienced with ROFGs should, if asked to do so, assist other FSR teams to set up other groups.

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7. See ATIP MP 88-11 for a discussion of these issues.

3.2.3 EXTENSION-ORIENTED FARMER GROUPS (EOFG)[8]

3.2.3.1 Justification

In 1987, the coordinators for the Communal First Development Area (CFDA) in the North East District requested DAR personnel in Francistown (ATIP) to assist them with agricultural development in their area. Part of the responsibilities of ATIP have been to assist in strengthening the MOA's capacity to develop, and effectively extend, improved production practices. Therefore, after discussions with the regional and district extension officers, research staff agreed to help design and test a system for accelerating extension efforts in the area of the CFDA.

Since the activity was geared towards extension rather than research, it was agreed that extension personnel should take the major responsibility for these tests. However, researchers were also to participate, to provide backup for extension officers, and to allow for a continuum between research and extension activities within the region.

By 1987, the group approach for conducting FMFI trials for research purposes, had been in use for two years. The potential for the group approach in extension activities had been recognized. After discussions among research, extension and CFDA personnel, it was therefore decided to adapt the ROFG approach for extension purposes, and to test this system in one village in the CFDA area. During the 1988-89 crop season, the testing was expanded to two villages. The resulting farmer groups have come to be known as Extension-Oriented Farmer Groups (EOFGs).

The objectives in testing the EOFG approach were to:

(a). Test a system for increasing the efficiency of Agricultural Demonstrators (ADs) by working with groups of farmers instead of relying on individual farm visits.

(b). Test the effectiveness of providing farmers with a series of technical options rather than a set production package, to take into account the heterogeneity in the farming community, and year to year climatic variations.

(c). Provide a forum, in the extension system, for research/extension interaction.

3.2.3.2 Approach

The approach used was similar to that of the ROFGs. It involved working with a group of volunteer farmers in selected extension areas. Within these groups, the farmers chose topics they were interested in, such as row planting methods, fertilizer application, etc. Extension and research staff jointly provided as many options as possible for addressing the topics (e.g., for farmers interested in row planting, four different types of row planters were presented). Individual farmers selected options that suited their own needs and resources, and tested them in their own fields. Then throughout the season, farmers, extension and research staff met monthly to discuss the tests and to deal with any problems that arose. Field days were held in late April, and an assessment of the performance of each technology option was made by the group at the end of the season. After the first years's test, an extension officer was assigned to act as a coordinator for both the EOFGs and the ALDEP Soil Conservation Groups in the North East District.

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8. These have also been called Extension-Led Farmer Groups.

In mid 1989, because of the demand for equipment that developed in the EOFGs, a system was set up to expedite the procedure for farmers to obtain ALDEP subsidies on equipment purchases, as long as they qualified for the ALDEP program.

The EOFGs differed from the ROFGs in that only "recommended" technologies were presented and farmers did not follow any conventional designs when implementing the tests. The only data collected by research were a Baseline Survey of participants resources, and an End-Of Season Farmer Assessment Survey.

A detailed description of EOFG activities, and the results of the activities and survey work done, are reported in the ATIP publications cited in Table 3.1 and 3.2.

3.2.3.3 Results and Conclusions

The EOFG approach was successful in several ways:

(a). There were approximately 20 volunteer farmer participants in each village. Attendance at monthly group meetings generally ranged from 10 to 15 farmers. The sustained farmer interest throughout the year indicated that the participants found the meetings useful, and felt that some of their own concerns were being addressed.

(b). The majority of participants did implement the trials they selected. Some of the technologies included: row planting, the use of a new inter-row cultivator, fodder crop production, and phosphate fertilizer application.

(c). After attending several group meetings, personnel from the Zwenshambe Brigade began to purchase fertilizer for sale to farmers. This was in response to complaints by farmers that they were unable to get ready access to fertilizer. Since then, the Brigade developed plans to expand the type of products they could supply, and to hire full-time personnel to participate in EOFG activities.

(d). An evaluation of the EOFGs by ALDEP personnel, in October 1989, resulted in the approach being included as part of the next ALDEP five-year plan. This was taken as a positive evaluation by an impartial evaluation team.

The EOFG approach provided a good forum for bringing together various participants in the extension process. At times, extension, research, ALDEP, the CFDA and the Zwenshambe Brigade personnel all worked together to address farmer problems through the EOFGs.

The major conclusions concerning EOFGs were as follows:

(a). The EOFGs were a more efficient way for ADs to interact with farmers on extension issues. Through the EOFGs, an AD could interact with 20 to 30 farmers by meeting with them one morning per month, whereas the same activity might have required the whole month when making individual farm visits.

(b). Group dynamics were helpful to farmers. For example, by testing a technology alone, a farmer could learn only about that particular technology. In the EOFGs, a farmer could learn about the technology he or she was testing, and also about the technologies that others were testing. Furthermore, in the EOFGs, farmers helped each other with ideas and suggestions, and did not have to rely solely on the AD for answers to all problems.

(c). The monthly meetings were an important backup system for farmers learning to use new technologies. Farmers almost always experienced difficulties when using new technologies for the first time. These difficulties could often be resolved at the monthly meetings. This was very important for the technology adoption process.

(d). The EOFG approach allowed farmers to be involved in teaching other farmers, through monthly discussions, and when they presented their work at field days. This possibly increased the speed of the extension process.

(e). The EOFG format provided a good forum for linking research, extension, NGOs, and farmers at the field level, to focus on extension issues.

(f). Presenting farmers with technology options rather than set packages allowed farmers to develop packages appropriate for their own resources.

(g). EOFGs represented a flexible approach which could be modified and adapted to meet local objectives, and to fit local resource constraints, wherever the approach was used.

(h). The most important factor in the EOFG approach was that extension and research personnel responded to farmers' expressed interests, and did not just present a standard set of recommendations.

In general, the EOFG approach has been found to be efficient and practical for ADs. The approach could have a significant impact on adoption rates if applied throughout a district.

3.2.3.4 Recommendations

The EOFGs were initiated to test a potentially useful accelerated extension approach. These tests have received a positive response among farmers and ADs. The EOFG approach has now been incorporated into the ALDEP extension activities at the national level. Also a **Promising Guideline** has been developed on how to organize and operate an EOFG [ATIP RP 6, Section 3.1.1]. Specific recommendations for future work are that:

(a). The two EOFGs currently operating should continue to be supported as usual, with ALDEP assuming responsibility for hiring the necessary field assistants.

(b). A pilot project should be initiated to expand the number EOFGs operating in the North East District, and possibly in the Mabalapye area -- where they could be supported by the FSR team as well as ALDEP. These EOFGs could be used to fine tune group management and support systems within ALDEP, and as training areas for ADs who are going to implement EOFGs in the future.

(c). Staff and farmers involved in the initial development of the EOFG approach should assist in the training of ADs who are going to start work with EOFGs in the 1990-91 season.

(d). One activity that would strengthen the EOFG approach would be to organize more intensive, in depth, training courses for EOFG participants on topics of special interest to them and where skills are required for certain technologies (e.g, row planting).

(e). An important advantage of the EOFG approach is that it could easily be combined

with other extension activities such as District Demonstration Farms (DDF), farmer training sessions, and competitions at Agricultural Shows. Such combinations could be highly effective.

3.3 FARMER TRAINING

3.3.1 JUSTIFICATION

Farmer training becomes particularly important when farmers need to acquire new skills to benefit from the adoption of a new technology or practice. A case in point is with respect to row planting -- to which ATIP has devoted considerable attention to over the years.

One of the benefits associated with row planting is improved percent establishment, which in turn is an important determinant of grain yield. On-farm work indicated an average of 35 percent establishment for row planting compared to about four percent for broadcast [ATIP, RP 1, p. 179].

However, variable results have been reported for row planting undertaken by farmers themselves [ATIP PR M89-1, p. 4]. It appeared that, although on average higher yields were produced from row planting, the variability in yields from the latter method, under farmer managed conditions, tended to be very high. This was often due to the lack of skill and experience of farmers with row planting.

To maximize the benefit from row planting, it was important to mechanically weed the fields that had been row planted. This was a practice that required considerable skill and was hardly ever performed by farmers.

Therefore, the objectives of the farmer training programs ATIP has been associated with, were the following:

(a). To provide practical training to farmers on when and how to row plant.
(b). To link row planting with mechanical weeding, by providing practical training on how to perform the latter.

3.3.2 APPROACH[9]

With respect to organizing the farmer training programs on row planting and mechanical weeding, the following were important aspects:

(a). A number of interested and concerned agencies helped in the training programs including regional and district extension staff, Rural Training Center staff (e.g., Mahalapye), Development Trust staff (e.g., Palapye), the Research Extension Liaison Officer, and research staff from both Sebele (e.g., FMDU) and ATIP.

(b). The location of the training was usually within a village setting, with camping accommodation provided by the Ministry of Agriculture and meals by the Rural Training Center. Generally, training was completed in about five days.

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[9]. Some details on organizing farmer training courses have been given elsewhere [ATIP RP 3, pp. 280-282; ATIP WP 29].

(c). Farmers were selected by ADs from a number of extension areas, although more tended to be selected from the village where the training was located. Farmers selected to participate in the training courses included those who had just acquired row planters.

(d). The courses had a strong practical orientation. Topics included:

i. How different planters operated with particular emphasis on the type of planters they used.

ii. How to select the correct seed plate or seed hole for the type of seed provided, and checking as to whether the seed dropped and was placed at the proper depth.

iii. Hitching the row planter to the donkeys, and performing the row planting operation itself.

iv. Hitching the cultivator to the donkeys, and then practicing the mechanical weeding operation itself.

v. Instruction on a number of other related topics such as the importance of good seedbed preparation, types of yokes/harnesses available, animal and equipment maintenance, etc.

3.3.3 RESULTS AND CONCLUSIONS[10]

During the 1988-89 season, 39 farmers -- 77 percent male and 33 percent female -- were trained on row planting in Mahalapye East and the Palapye Districts. An impact assessment conducted after harvest indicated that of the 29 farmers monitored, 66 percent row planted but only 21 percent of farmers were able to mechanically weed.

When training for the 1989-90 season was planned, it was decided that more women should participate, and that husband and wife teams would be desirable.[11] It was felt that, since women were involved in weeding, their participation would enhance the success of the mechanical weeding operation. The composition of the 45 participants during the training were 58 percent males and 42 percent female. Twenty-four percent of the 45 farmers were husband and wife teams.

During the 1989-90 season, participants who had participated in the training failed to row plant or mechanically weed on their own fields. This result was disappointing but should not discourage the development of future farmer training program. All participants had indicated an interest in row planting, in training, and had purchased equipment through ALDEP. In this instance, farmers indicated that the late beginning to the rains and the urgency to plow a large area under ARAP contributed to the decision not to row plant.

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[10]. See ATIP WP 29 for a more detailed discussion on the impact of farmer training courses.

[11]. In the first season there were none.

3.3.4 RECOMMENDATIONS

There is no question that farmer training courses involving "hands on" experience, can play an important role in stimulating correct adoption of complex improved technologies. Row planting is a good example of such a technology. Because of the value of farmer training courses, a **Promising Guideline** has been prepared [ATIP RP 6, Section 3.1.2].

It is hoped that farmer training courses will continue to receive some emphasis for specific technologies. With respect to this, the following is recommended:

(a). DAOs should be the appropriate officers to identify the need for farmer training. The DAO, the Rural Training Center, and the Crop Production Officer should take the lead in organizing farmer training. Research and Development Trust staff can provide support, including trainers, and could conduct assessment studies[12] of individual courses.[13]

(b). Where possible, farmer training courses should be combined with and/or complemented by other supporting activities. For example, it may be appropriate to run farmer training courses for farmers in specific extension area(s), for farmers associated with a particular EOFG, etc. An example of a complementary activity would be to link the provision of ALDEP row planting packages with farmer training courses.

(c). Continue the research follow-up to training courses to assess the impact of the training, and to identify problem areas and possible solutions

(d). Develop an effective extension follow-up specifically targeted for the participants of the training courses, and to help resolve problems encountered.

3.4 FARMER FIELD DAYS

3.4.1 JUSTIFICATION

Farmer field days have been in common use in both research and extension programs, worldwide, for a long time. They serve many useful purposes, including the following:

(a). For a research program, they are a good way of exposing the work to the public (i.e., farmers, extension personnel, and other researchers) and obtaining outside evaluations of the program.

(b). Farmer field days can help to ensure that both farmers and extension personnel become familiar with new technologies as they develop. This can greatly ease the process of extension and adoption, once the technologies move to the dissemination

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[12]. Staff from the Rural Sociology Unit, Division of Planning and Statistics, have proved to be particularly helpful in this activity.

[13]. This approach, was agreed to at a recent meeting of research and extension staff in the Central Agricultural Region, chaired by the Regional Agricultural Officer. The meeting was held in Mahalapye on May 2nd, 1990 [Anon, 1990].

stage.

(c). When conducted by an FSR team, they provide an opportunity for on-station researchers to see how technologies are performing in the field, and to discuss them with a large group of farmers.

(d). They can provide an opportunity for farmer participants in the FSR program to show off the work they have been doing.

(e). Field days can be used as the first stage of an extension program once technologies are ready for wide scale adoption by farmers.

3.4.2 APPROACH

The particular approach that ATIP has used for conducting farmer field days has varied slightly, depending on the specific objectives involved. However, the following steps were generally applied:

(a). ***Planning.*** Planning of field days was done in collaboration with farmers in the research program, from the villages where the field day was to take place. The role of farmers has increased significantly over time. In more recent years, participating farmers have assisted in raising funds for food and refreshments. Also sometimes farmers' committees, in the villages, have been involved. Village, and often district and regional extension staff were also included. Joint planning included deciding on the date for the field day, selection of technologies and fields to be shown, deciding who to invite, finalizing food and transport arrangements, and setting an agenda for the day.

(b). ***Audience.*** Within the host village, normally all farmers were invited. The number of visitors from other villages was often limited by a lack of transport, but usually a group of farmers was invited from other villages where the research team was operating. All researchers within DAR were invited, and often representatives from NGOs. Extension personnel usually decided who to invite within their department and arranged transport for the same.

(c). ***Presentations.*** The field day generally began with the local head man or other dignitary welcoming any visitors. Following this, an overview of the research program and the days planned activities was given by research staff and the group then moved on to visit the specific research sites. RM trials were generally presented by researchers, while FM trials were normally presented by the farmer-implementer. Presentations were always followed by discussion sessions. At the end of the day there was a wrap-up session for summarizing the day's observations and general discussion.

3.4.3 RESULTS AND CONCLUSIONS

Within ATIP, farmer field days have been regularly held. However, they have always been viewed as a non-research activity and therefore have not been described in detail in ATIP

reports.[14]

Experience gained from farmer field days has been presented elsewhere [ATIP RP 3, pp. 277-280].

Some observations on the effectiveness of farmer field days were as follows:

(a). Farmer field days were generally a popular activity, normally attended by from 70 to 120 people. Roughly eighty percent of the audience were farmers, with 20 percent research and extension personnel. Of the farmers, attendance was commonly dominated by women, with up to 90 percent women in some of the events in the Francistown area. In the Mahalapye area, attendance by men and women was almost equitable.

(b). The farmer field days were very successful in stimulating discussion among participants. This was especially true when trials results were presented by the farmers, that is, the implementers.

(c). The farmer field days were also effective in generating interest in the use of new technologies among farmers, and a spirit of competition between villages in terms of their overall farming skills.

(d). These farmer field days proved to be a useful and efficient forum for sharing ideas among farmers, and between researchers, extension personnel and farmers.

3.4.4 RECOMMENDATIONS

Recommendations for future action, in addition to the **Promising Guideline** which has already been produced [ATIP RP 6, Section 3.1.3], are as follows:

(a). As far as possible, efforts should be made to continue farmer field days. These activities serve to generate interest in new technologies. They are an important forum for keeping extension personnel and the public informed about research activities, and for generating ideas to improve research.

(b). The source of funds for providing food to guests is an issue that needs to be addressed. Planners will need to seek funding if field days are to extend through the whole day.[15]

3.5 COMPETITIONS AT AGRICULTURAL SHOWS

3.5.1 JUSTIFICATION

Agricultural Shows are held throughout the country each year. These shows give specific recognition to livestock producers, particularly with reference to prime beef producers.

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[14]. ATIP references on Farmer Field Days include the following: RD 84-1 [p. 7.36]; RD 85-1 [pp. 7.42, 8.45]; RD 86-1, [p. 109]; RD 87-1 [pp.II.58, II.80]; RD 88-2 [p. 49]; RD 89-2 [p. 66].

[15]. Some suggestions on how to obtain funds are given in ATIP RP 6, Section 3.1.3.

However, in general, very little recognition is given to arable producers, except with reference to evaluating the quality of small samples of harvested production, such as cowpeas, sorghum, etc. Techniques used in arable farming receive no attention. Therefore in 1988, ATIP initiated, with the help of extension -- including ALDEP and the Mahalapye Rural Training Center staff -- an arable-related contest at the Mahalapye Agricultural Show. The idea was to provide entertainment while, at the same time, conveying a message. The focus of the competition was row planting and the related operation of mechanical weeding.

3.5.2 APPROACH[16]

As a result of experience, ATIP has used the following approach:

(a). A single Organizing Committee was set up consisting of relevant ALDEP, extension, rural training center, and research staff operating in the area. Each participating agency was then assigned appropriate responsibilities.

(b). Contestants, usually about six per Agricultural Show, were selected by ADs, as the best row planters in their extension areas. The contestants were expected to provide their own donkeys for the contest.

(c). It was important for the Organizing Committee to ensure that:

i. The Agricultural Show Committee agreed to the contest being held, and allocated a time slot and land for the purpose.

ii. The evaluation and judging criteria were agreed to by all parties, and were adequately explained to the contestants.

iii. The land at the Agricultural Show was properly prepared and demarcated; the necessary equipment assembled; kraals constructed and food and water made available for the animals; and the appropriate fencing, posters and banners put up.

iv. Accommodation and food was arranged for the participants.

v. Appropriate judges were selected.

vi. A commentator was selected and provided with an appropriate sound system and introductory commentary notes on the contest and contestants.

vii. Appropriate prizes were obtained and given to the contestants.

3.5.3 RESULTS AND CONCLUSIONS

To date, ATIP has directly participated in organizing competitions at three Agricultural Shows, and has had indirect involvement in five others. Generally about six farmers have been involved in the competitions at each show. The competitions have been popular with the farmers and with ALDEP and other extension staff. Based on ATIP's experience it

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[16]. Further details on organizing competitions at Agricultural Shows can be obtained from ATIP WP 28 and ATIP RP 3, pp. 282-284.

appeared that the time slot the competition is allocated at the show is important in determining how much attention is paid to the competition by the general public.

3.5.4 RECOMMENDATIONS

Although ATIP played an important catalytic role in getting the row planting contests started at Agricultural Shows, it is not considered appropriate that it should continue to play a leadership role. The recent proposal by ALDEP [1990] to take over this role is therefore fully supported. This has also recently been agreed to by those attending a meeting of research and extension staff in the Central Agricultural Region, which was chaired by the Regional Agricultural Officer (RAO)[17] [Anon, 1990].

A **Promising Guideline** has been prepared on organizing competitions or Agricultural Shows [ATIP RP 6, Section 3.1.4].

It is proposed that the Action Research Unit in the Agricultural Information Division of the MOA be requested to ascertain how the competitions could be further improved in order to maximize the interest by the general public.

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[17]. Held in Mahalapye on May 2nd, 1990.

CHAPTER 4: SYSTEM TECHNOLOGIES

4.1 SYSTEM TECHNOLOGIES

Much of ATIP's work has been focussed on system type technologies -- those that are not crop specific. The major reason for this has been that farmers have most often articulated issues that relate back to limited soil moisture as being the major constraint they face in their farming systems. This constraint, in turn, has led to a great deal of focus on issues related to tillage. Soil moisture availability, critically important in plant establishment and growth, can be enhanced through three general strategies:

(a). Concentrating the limited amounts of rainfall onto and/or within certain parts of the field.
(b). Ensuring more water infiltrates into the soil profile rather than being lost through run-off.
(c). Ensuring that the soil moisture is used more efficiently in terms of increased crop production. Crop production in a low input system is often a function of plant establishment.

Of course these strategies are not mutually exclusive, and in fact many of the topics discussed in this chapter, reflect the incorporation of elements of more than one of these. The major topics considered in this chapter are:

(a). Technologies relating to different types of tillage, particularly those linked with early plowing options, and reduced or alternative primary tillage operations (Section 4.2).

(b). Issues related to tillage such as plant establishment, weed control, land-type, and fertilizer (Section 4.3).

(c). Issues relating to planting methods and post-establishment practices such as row planting versus broadcasting, methods and problems of row planting, plant population control, and weeding (Section 4.4).

(d). Semi-permanent field development, specifically relating to rainfall run-off management strategies and soil fertility issues (Section 4.5).

In general, the types of technologies discussed in this chapter represent high leverage interventions, that if suitable for farmers, could potentially have a major impact on the productivity of the farming system.

4.2 TILLAGE TECHNOLOGIES

4.2.1 EARLY PLOWING OPTIONS

4.2.1.1 Justification

Soil moisture for plant growth is clearly the major environmental constraint to crop production in Botswana. The generally low level of precipitation and the low moisture holding capacity of the soils combine to restrict potential productivity in much of the country. The erratic nature of precipitation during the growing season also introduces a high

level of risk for cropping activities that must be addressed before farmers will be willing to make the investments required to increase crop production.

These observations are self-evident in the main, but have also been supported in the early descriptive and diagnostic research conducted by the ATIP.

Establishing a crop plant population sufficient to meet target yield goals is a necessary precondition for achieving satisfactory levels of crop production, and making efficient use of soil moisture. Early field studies by ATIP indicated that farmers in the study areas also had some difficulty in achieving good stands with any reliability.

Because of the critical importance of increasing available soil moisture for plant growth and the difficulties observed with reliable plant stand establishment, agronomic research in ATIP has focussed on these issues almost from the outset of the project. One of the primary approaches for addressing these issues has been through improved tillage and planting practices.

Within the tillage/planting arena, the concepts of "early plowing" and "double plowing" have proved to be two of the simplest and most effective tools. While ATIP did not initiate these concepts, it has done extensive work in testing their effectiveness on-farm, and examined numerous options for their inclusion in practical production systems. Table 4.1 provides a list of the work done and the relevant publications. Results from this work form the basis of the discussion in the following sections.

In the context of this report, "early plowing" refers to a preliminary plowing (without planting) in either winter or early spring (usually the latter). This early plowing may or may not be followed by a second tillage operation at planting time. In the same sections, "double plowing" refers to a system in which the soil is plowed (without planting) and then later re-plowed at planting time, usually with one or two rainfall events of more than 10 millimeters between the two plowings. Thus early plowing may be a part of the double plowing system, but the two are not the same.

Furthermore, because of the extensive amounts of research done on both early plowing and double plowing (Table 4.1), only documents which summarize several years of work on particular aspects will be referred to in the text.

4.2.1.2 Results And Conclusions

Although the following discussion is presented in terms of a technology ladder, it is important to bear in mind that as moves up the ladder take place, the range of options open to the farmer increases. The choice of technology options also depends on the prevailing climatic conditions when a farmer is ready to plant, and on his/her resource constraints which also vary throughout the season. As a result, it may be perfectly rational for farmers, on occasion, to simultaneously use, on different parts of the farm, technologies associated with different steps up the technology ladder.[1] The steps up the technology ladder which are examined in the following sub-sections are:

(a). Double plowing with broadcast planting.
(b). Early plowing plus row planting.
(c). Early plowing and an additional cultivation plus row planting.

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[1]. See Section 1.3.1 for a further discussion on this topic.

TABLE 4.1: ATIP ACTIVITIES RELATING TO TILLAGE TECHNOLOGIES INVOLVING EARLY PLOWING

MAJOR FOCUS	MORE DETAILS	YEAR	AREA	SAMPLE[a]	TYPE[b]	TRIAL	ATIP PAPERS		
Draft tractors:	Animal management for early plowing	1984	F'Town	6	Trial	RMFI	RD 85-1, p.8.27-8.34	MP 85-12	PRF86-3,PRF87-5 RD 86-1,p.98-100
	Tractors for early plowing	1984	F'Town	4	Trial	RMFI	RD 85-1, p.8.35-8.37		
	Draft management	1983	Mahal.	4	Trial	RMFI	RD 84-1, p.7.31-32	RP 1, p.195-197	
Technology components:	Maximum production	1983-4	F'Town	3,3	Trial	RMRI	RD 84-1, p.8.20-8.23	RD 85-1, p.8.5-8.11	WP 5, p.3-8,12-13
	Steps in technology	1983-4	F'Town	3,3	Trial	RMFI	RD 84-1, p.8.23-8.25	RD 85-1, p.8.37-8.40	WP 5, p.8-13
	Commercial steps in technology	1984-6	Mahal.	4,5,5	Trial	RMRI	RD 85-1, p.7.26-7.30	RD 86-1, p.54-57	
Tillage systems:	Double plowing (miscellaneous)						RD 87-1, p.II.37-39		
		1982	Mahal.	2	Trial	RMFI	RD 83-1, p.V.29-30		
		1986	F'Town	4,5	Trial	RMFI	RD 87-1, p.II.70-72	PR F86-3	PR F87-5
		1985-6	F'Town	12	Trial	FMFI	RD 86-1, p.105-107		
		1985-6	Mahal.	32,14	Trial	RMFI	RD 86-1, p.59-62	RD 87-1, p.II.44-47	MP 88-6
		1987	Not Sp.	---	Paper	--	MP 87-6	PR F90-3	
		1987-8	F'Town	6,6	Trial	RMFI	RD 88-2, p.55-56	RD 89-2, p.71-75	PR F89-1
	Through farmer groups	1985-9	F'Town	12,62	Trial	FMFI	RD 88-2, p.63-68	RD 87-1, p.II.74-78	
		1985-89	F'Town	12	Trial	FMFI	RD 86-1, p.105-107	PR F86-2	
			F'Town	101	Trial	FMFI	RD 87-1, p.II.74-II.78	PR F87-6	
			F'Town	93	Trial	FMFI	RD 88-2, p.63-68	PR F90-2	
			F'Town	51	Trial	FMFI	RD 89-2, p.88-90	PR F90-6	
	Effect of soil-type	1988	Mahal.	---	Paper	---	MP 88-6	EP 90-1	
	Potential and factors affecting	1988	Both.	---	Paper	---	MP 88-17	EP 89-4	
	Double plowing plus other systems:	1983	Mahal.	2	Trial	RMRI	RD 84-1, p.7.26-7.27		
		1983	Mahal.	9	Trial	RMFI	RD 84-1, p.7.30-7.31	RP 1 p.174-193	
		1984	Mahal.	7	Trial	RMFI	RD 85-1, p.7.34-7.38	RP 1 p.174-193	
		1985-6	Mahal.	3,2	Trial	RMRI	RD 86-1, p.57-58	RD 87-1, p.II.35-37	
		1985-6	F'Town	2,2	Trial	RMRI	RD 86-1, p.96-98	RD 87-1, p.II.68-70	
							PR F86-5	PR F87-8	
		1987	Mahal.	---	Paper	---	MP 87-3		
	Weeds and weeding labor	1987	F'Town	---	Paper	---	MP 87-7		
		1987	Mahal.	---	Paper	---	MP 87-9		
	National tillage trials	1988-9	Mahal.	3	Trial	RMRI	RD 89-2, p.50		
		1988-9	F'Town	2	Trial	RMRI	RD 89-2, p.75-79	PR F90-4	

a. Refers to the number of sites or farmers. RMRI trials will usually have more than one replication at each site. Figures in the column separated by a comma indicate sample sizes in different years.

b. This can refer to a study, survey, trial or paper.

Before looking at these steps, it is important to understand the implications concerning the opportunity costs of the early plowing operation. In this context, the opportunity cost of early plowing has been defined as the amount of grain that a farmer might have obtained by plowing and planting, instead of plowing without planting, at the time when the early plowing was done. This can be estimated by planting a plot adjacent to the early plowed area, on the day of first plowing. If the planted area fails to produce a yield, then the opportunity cost of the early plowing was probably zero. However, if the adjacent plot yields well, then the opportunity cost was high. The question of this opportunity cost is extremely important because it has a direct bearing on whether a farmer would be better off from doing the early plowing, versus using the traditional single plow system in place of the early plowing.

In fact, ATIP has conducted several trials to examine opportunity costs. Results of some of these trials have been analyzed -- see, for example ATIP MP 87-6. Results, to date, indicated that in order for early plowing -- with animal traction -- to be more productive and profitable than the traditional single plow system, the opportunity cost of the early plowing had to be held as low as possible. To achieve this it was essential to do the early plowing at non-optimal planting times. Two possible ways to do this were either to:

(a). Take advantage of very early rains in the planting season and early plow before the accepted planting season began, or

(b). Use the period after a rain when the soil could be plowed, but was too dry to ensure good plant stands, and preliminary plow without planting.

Using periods of good soil moisture to plow without planting represented a loss of valuable and extremely limited planting time, and was not always beneficial in the long-run.

(a). ***Double Plowing With Broadcast Planting.*** The double plowing option represents a first step up the technology ladder. It is a low input technology in that it requires no new inputs, equipment or skills, but it can have a dramatic effect on per hectare grain yields.

A large body of research on double plowing with broadcast planting, and using animal draft power was summarized in July of 1989 [Heinrich, MacPherson, Norman, Patrick and Siebert, 1990].[2] The data surveyed were largely from ATIP research, but also included research conducted outside ATIP. Conclusions stated in the report, and accepted by the Soil and Water Management Group at Sebele were as follows:

i. Compared with the traditional system, planted on the same day, double plowing generally increased per hectare grain yields of sorghum and millet by 50 to 100 percent, given sufficient rainfall to produce a crop yield (Tables 4.2 and 4.3).[3]

ii. Regarding the timing of the first plowing, generally speaking, the earlier this was done, the better -- hence the current recommendations for autumn/winter

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[2]. This paper formed the basis for approving an **Agrifact** to be produced on double plowing.

[3]. These tables, from Heinrich et al., [1990], are largely derived from data in ATIP MP 87-6.

plowing,[4] or early spring plowing. However, for animal draft users who could not start very early, a benefit was to be expected from a preliminary plowing operation performed even in mid to late planting season, as long as there was sufficient post-planting rainfall to produce some yield.

TABLE 4.2: PAIRED COMPARISONS OF CROP YIELDS (KGS/HA) OF DOUBLE AND SINGLE PLOWING, FRANCISTOWN, 1983-88

CROP	YEAR[a]	YIELD DP[b]	YIELD SP[b]	% YIELD INCREASE	NOS. OF OBS.
Sorghum	1983-85	459 **	238	93	18
	1985-86	489 **	254	92	12
	1986-87	201 ***	99	103	21
	1987-88	604 *	340	78	11
	All years	406 ***	214	94	62
Millet	1983-85	677 n.s.	365	85	7
	1985-86	390 *	240	63	9
	1986-87	175 n.s.	103	70	10
	1987-88	427 **	253	69	18
	All Years	402 ***	234	72	44
Cowpeas	1985-86	920	472	95	1
	1986-87	156 *	99	58	12
	1987-88	181 **	130	39	30
	All Years	191 **	129	48	43

Source: Various trials listed in Table 4.1

a. 1983-85 includes only RM trials; 1985-86 includes RM and FM trials; 1986-87 includes both RM and FM trials; 1987-88 includes only FM trials

b. Figures in this column represent yields from double plowing. N.s. denotes no significant differences, and *, **, *** denote significant differences at the probability level of 95, 99 and 99.9 percent, respectively.

c. The figures in this column reflect the yield from traditional broadcast/planting plots planted on the same day as the double plowed plots.

TABLE 4.3: RELIABILITY OF THE EFFECT OF DOUBLE PLOWING, FRANCISTOWN, 1983-88[a]

	-- PERCENT OF PAIRED COMPARISONS -- CEREALS[b]	ALL 3 CROPS[c]
Yield of DP was greater than SP	92	91
Yield of DP was at least 50% greater	81	67
Yield of DP was at least 100 kg/ha greater	68	59

Source: Data from trials used in constructing Table 4.2.

a. DP refers to double plowing and SP denotes single plowing.

b. Cereals include sorghum and millet data sets only.

c. All three crops include sorghum, millet and cowpea data sets.

iii. In plot comparisons it was observed that when adequate soil moisture was available, weed growth was greater in the early plowed plots. If the period between the two plowings was substantial, this could lead to a depletion of moisture reserves and difficulties in plow/broadcasting.

iv. Double plowing significantly reduced infestation of the perennial grass Cynodon dactylon. It also reduced the level of other perennial species, but its effect on annuals was variable. Double plowing sometimes increased and other times decreased weed burdens and subsequent weeding times. When

[4] Unfortunately few farmers adopted this practice because livestock grazed on crop residues following harvest. After this, the ground was too hard to permit plowing with the traction available to most farmers.

double plowing caused germination of weeds that could be destroyed when small, it was beneficial to control them. This also reduced the weeding labor requirement at a later date.

v. The effect of double plowing was thought to be greater and more consistent, on deeper soils with higher moisture holding capacity, but less effective on shallow soils with a lower moisture holding capacity.[5]

vi. It was generally agreed upon among researchers, that there were too few planting opportunities in a normal season for them to be wasted on plowing without planting -- that is, land preparation only. Furthermore, when the preliminary plowing was done during a good planting opportunity (i.e., when good soil moisture was available during prime planting season), then the opportunity cost of plowing without planting possibly made the double plowing system unprofitable. For these reasons it has been concluded that the preliminary plowing of the double plowing system must be performed when the opportunity cost is low (i.e., during non-optimal planting conditions) for the double plowing system to be generally profitable.

vii. Economic studies of double plowing in the Tutume Agricultural District (Tables 4.4 and 4.5) have indicated that the switch from traditional to double plowing would be most beneficial for farmers who control their own draft power, but are faced with either a weeding labor constraint, or a land constraint. Double plowing was not only more profitable but was more reliable.

It is important to note that the above conclusions are specific to the use of animal draft. There is still some question about the profitability of using tractors to implement the double plowing system, because tractor draft is more expensive than animal draft.[6] Also, when tractors are involved in the tillage system, farmers who own tractors have access to more power, more speed and more systems' options.

(b). ***Early Plowing Plus Row Planting.*** The theory behind early plowing is that it can increase the rate of infiltration of rainfall into the soil, thereby reducing run-off and developing a reserve of stored soil moisture. The reserve of moisture can result in improved seedling establishment, better crop growth, increased grain yield and reduced risk of crop loss. This theory holds whether or not a secondary tillage operation is applied at planting. Evidence to support this hypothesis -- particularly regarding soil moisture -- has been presented elsewhere [ATIP EP 89-4].

In addition, once early plowing has been done, the period of optimal soil moisture that follows the next good rain may be used entirely for row planting. Since row planting is faster than plowing, this might mean that farmers could plant larger areas during a given planting opportunity.

This being the case, it might be expected that early plowing -- particularly in periods

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[5]. See Section 4.3.3 in general, and Table 4.7 for further discussion on this.

[6]. Double plowing is one of the treatments currently being compared in the National Tillage Trial. Tractors are being used in this multi-locational research managed and implemented trial, which should therefore help shed some light on this issue.

TABLE 4.4: 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 ATIP MP 87-6, 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 times 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 is contrary to what has occurred in 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 doubl plowed plots even more attractive.

TABLE 4.5: RELIABILITY OF THE RETURNS PER UNIT OF LAND AND LABOR FROM DOUBLE PLOWING, FRANCISTOWN, 1985-87[a]

MAGNITUDE OF COMPARISON	% OF COMPARED COMPARISONS SP	SP2[b]
Gross return/ha of DP was:		
Greater than SP	85	55 (P96.76)
Net return/ha of DP was:		
Greater than SP	80	55 (P91.36)
At least P20.00/ha greater	50	40
At least P100.00/ha greater	10	5
Net return per land preparation hour of DP was:		
Greater than SP	50	70 (P0.60)
Greater than P0.38/hour (drought relief wage)	40	45
Greater than P0.53/hour (minimum urban wage)	25	40
Net return per hour of weeding DP plot was:		
Greater than SP	59	61 (P0.46)[c]
Greater than P0.38/hour (drought relief wage)	30	45
Greater than P0.53/hour (minimum urban wage)	25	45
Net return per "total" hour spent on the DP plot was:		
Greater than SP	55	70 (P0.39)
Greater than P0.38/hour (drought relief wage)	15	30
Greater than P0.53/hour (minimum urban wage)	15	20

a. The figures in this table are calculated from the trials analyzed in Table 4.4.

b. These results describe the comparison of double plowing a single hectare versus single plowing two hectares in which the first hectare is planted at the time of the first plowing. The combined results from this planting and that from the hectare planted on the same day as double plowing are, however, not really a valid comparison with double plowing, since it is recommended that the first plowing is done when there is not enough soil moisture for planting (i.e., the yield for planting at this time would approach zero). The figures in brackets reflect the average values of the two hectares combined.

c. Average weeding time on these plots was 89 hours/two hectares.

of low opportunity cost -- could be beneficial for crop yields. Row planting might be preferable to a second plowing at planting time because it would be faster and would have a lower draft requirement.

Experiments conducted by the ATIP team in Mahalapye have shown some grain yield benefits to this "early plow/row plant" system when compared against a system of single plowing and row planting on the same day [ATIP RD 87-1, p. II.37). However, these experiments also indicated that more attention to weed control might be required with this particular method because of the lack of tillage at the time of planting -- that is, weeds may start to grow even before crop seeds are planted. Row planting would allow mechanical weed control to be employed, and this has been suggested as an approach for dealing with the problem.

The use of an early plowing plus row planting system represents a step up the technological ladder from the traditional broadcast single plow and broadcast double plow systems. Row planting requires a more precise timing of operations, new skills on the part of the farmer,[7] and often, the purchase of new equipment.

(c). ***Early Plowing, And An Additional Cultivation Plus Row Planting.*** The next step up the technological ladder, beyond the two-step operations, could be a system that includes a double tillage operation plus row planting -- that is, a three-step process. Such systems could include:

i. Double plowing plus row planting,
ii. Early plowing followed by a cultivation on the date of planting, plus row planting, or
iii. Early plowing followed by harrowing and row planting.

The three-step system may well prove to be the most productive, though it is more complicated than the two-step systems described above. Double plowing and broadcast planting has been shown to be more productive than single plowing and broadcast planting in animal draft systems. Similarly, row planting has been shown to be more productive than broadcast planting -- for example, see ATIP WP 5.

The purposes of early tillage, and double tillage, are to increase the soil moisture available for plant growth, to control weeds and to improve soil tilth. The purposes for row planting are primarily to:

i. Achieve improved plant distribution within the field and thus use the environmental resources more efficiently.
ii. Place the seed at the proper depth to enhance seedling emergence and stand establishment.
iii. Facilitate mechanical weed control.

Thus the purposes for early tillage and/or double tillage operations are quite different from those of row planting, and combining the two technologies into one system might be expected to produce synergistic effects.

To date, little information has been published by ATIP comparing the three-step system with the one- or two-step options discussed above. This is because most of

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[7]. See Sections 3.3 and 4.4.3 for further discussion on this.

the research has focused on the other systems. A focus on the other systems was thought to be more important because most farmers in the ATIP study areas were still using only the broadcast/single plow system. It is likely that a three-step system would be most appropriate on a contingency basis, for example, when weeds or soil conditions are a problem at planting time.

4.2.1.3 Recommendations

Recommendations consist of the following:

(a). Recommendations for the extension of the double plowing option with animal draft have been approved as an **Agrifact** and will soon become part of the extension program. Also a **Promising Guideline** on early plowing has been produced [ATIP RP 6, Section 2.1.1].

(b). The early plowing plus row planting system with animal traction has shown some potential for increasing per hectare grain yields. Further examination should be made of the economics, farmer evaluation, risk and weed problems involved with this system.

(c). Specific trials should be initiated on-farm to examine the yield potential and economics of the double plow and row plant, and early plow, cultivate, row plant systems using animal draft, and to obtain farmer evaluations of the same. These should, at a minimum, be compared against the single plow/broadcast system and the double plow/broadcast system.

(d). There may be some differences in the performance of similar tillage systems when implemented by tractor and by animal draft. This issue should be examined in specifically designed trials, in order to determine whether separate tillage systems need to be developed for the different types of draft power.

(e). The system of early plowing by tractor, followed by a second plowing by animals showed mixed results in terms of yield and economic benefits in Francistown during 1987-88 and 1988-89 [ATIP PR F89-1; ATIP PR F90-3]. Nevertheless, this is one of the more practical systems and could be used by the majority of farmers. Further studies should be implemented to see if this could be molded into a viable and beneficial system.

4.2.2 NON-PLOWING OPTIONS

4.2.2.1 Reduced Or Alternative Primary Tillage

(a). ***Justification.*** This section summarizes observations that have been made on primary tillage options other than conventional plowing. Alternative tillage has been investigated for two reasons:

i. The tillage resource constraint is experienced by nearly all households. Either households have limited access to tillage resources, or the resources that are available are not adequate to plow and plant the field in a timely manner. This certainly is the case for farmers using animal traction in years when rainfall is erratic during the plowing and planting period. Because of this constraint, large portions of fields have poor rainfall infiltration and heavy

weed growth during the early part of the season. Alternative tillage which is more rapid than conventional plowing could help solve this problem provided the tillage is effective.

ii. Alternative tillage could have long-term benefits for the soil structure that come from reducing or eliminating moldboard plowing.

The two types of alternative tillage options that have been examined in the ATIP program are:

i. Use of a spiked tooth harrow to scratch the soil surface following the first spring rains.
ii. Use of chisel plowing -- narrow tined cultivator -- in lieu of conventional plowing both early in the spring and at the standard plowing and planting time.

The objectives of research on alternative tillage were to evaluate:

i. The manageability of the option by resource poor farmers.
ii. The cost in terms of time and draft energy required.
iii. The effectiveness of these systems in improving water conservation, tilth for planting and weed control.

Even though little work was done in the area of alternative primary tillage, it is useful to present the observations and the reasons for the decision not to continue working on alternative tillage in the on-farm research program. Alternative tillage options were investigated in only two trials, both of which used tractor draft and were largely RMRI (Table 4.6). Concerning the two trials:

i. In the first, the use of an early season harrowing on untilled land was done in a type of superimposed trial. In this trial, the harrowing, and moldboard plowing (i.e., both deep and shallow) comparisons were followed by the farmer's own operation (i.e., broadcast and conventional plowing).

ii. In the second, the chisel plowing was part of a standard RMRI trial in which several systems designed to improve water conservation were compared. Chisel plowing was implemented in two years of the Water Conservation Systems Trial. However, results were only recorded for the first year. Results of the second year were similar to that of the first, except that no grain yield was taken.

(b). ***Results And Conclusions***. Results from the trials indicated the following:

i. Early season harrowing was not effective. Even though harrowing proved to be more than four times as rapid as conventional plowing,[8] harrowing was not effective as an early season tillage operation. Water infiltration did not seem to be improved nor were weeds very well controlled. It was observed that following harrowing, the soil surface became more dense than the untilled land and certainly more dense than land that had been plowed with a moldboard plow.

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[8]. Comparing a tractor drawn two furrow moldboard plow with three spike tooth harrow units drawn by a tractor.

TABLE 4.6 ATIP ACTIVITIES RELATING TO NON PLOWING OPTIONS

MAJOR FOCUS	MORE DETAILS	YEAR[a]	AREA	SAMPLE[b]	TYPE[c]	TRIAL	ATIP PAPERS		
Reduced tillage	Harrowing	1983	Mahal	2	Trial	RMRI	RD 84-1, p.7 26-27		
	Chisel plow	1985	Mahal	3	Trial	RMRI	RD 86-1, p 57-58	RD 87-1, p.II 35-37	
Precision Deep rip	Pre-plowing option	1984-5	Mahal	3,3	Trial	RMRI	RD 85-1, p 7 26-30 RP 1 p.167-173	RD 86-1, p.54-57	
	Precision deep rip system	1985-6	Mahal	3,2	Trial	RMRI	RD 86-1, p 57-58 RD 87-2, p 7	RD 87-1, p II 35-37 MP 87-9, p 4	
		1985-6	F'Town	2,	Trial	RMRI	RD 86-1, p 96-98	RD 87-1, p II 68-70	PR F87-8
		1988-9	Mahal	3,2	Trial	RMRI	RD 89-2, p 50		
		1988-9	F'Town	2,2	Trial	RMRI	RD 89-2, p 75-79	PR F90-4	

a The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season, and 1984-5 refers to both the 1984-85 and 1985-86 cropping seasons

b Refers to the number of sites or farmers. RMRI trials will usually have more than one replication at each site. Figures in the column separated by a comma indicate sample sizes in different years

c This can refer to a study, survey, trial or paper.

ii. Chisel plowing appeared, at least initially, to give a more favorable response than harrowing. Even though operation times were not recorded for chisel plowing, a tractor drawn cultivator was able to work as fast or slightly faster than conventional moldboard plowing. What was important to note was that chisel plowing could easily be implemented on soil moisture that was just barely adequate for moldboard plowing. ATIP researchers felt that, from an operational viewpoint, chisel plowing could be implemented by any farmers using tractors.

Initially, chisel plowing appeared to provide a satisfactory tilth for row planting on soil-types ranging from loamy sand to sandy clay loam [DAR, 1987, p. 100]. Plant establishment and early plant growth compared favorably with that found under the best conventional plowing. However, sorghum growth, under chisel plowing, was more dramatically affected by drought stress during mid- and late-season than under double plowing or early plowing plus row planting. This was reflected in modest grain yield and plant height responses for sorghum under chisel plowing [DAR, 1987, p. 100]. Weed burdens, under chisel plowing, were reasonably well controlled although the soil was not inverted.

One critical result of work on alternate primary tillage was that farmers participating in the program failed completely to endorse these options.

Therefore decisions made and conclusions reached, were the following:

i. After the 1983-84 season, it was decided that no more work would be done with harrowing as a primary tillage operation. In subsequent years, harrowing was only used as a seedbed preparation, either for broadcast seeding or for preparing plowed land for row planting. However, even under these circumstances, harrowing continued to result in increased surface bulk density. Agronomists in the project felt that harrowing tended to cause excessive break down of aggregates in most soils. These soils already had poor structure and were prone to rapid clod disaggregation and soil slumping during the season. A further decision was reached not to include harrowing in trials, and not to encourage harrowing except to improve excessively cloddy seedbeds before row planting.

ii. Chisel plowing appeared to have some potential for small farmers. It could be readily implemented, even on comparatively dry soils. However, the effectiveness of this tillage was limited compared with conventional moldboard plowing. The susceptibility of sorghum to drought under chisel plowing was probably due to the inadequate loosening of soil. The problems with chisel plowing and other tillage that failed to loosen a large volume of soil, was reflected in the greater susceptibility of sorghum to moisture stress under chisel plowing than under conventional moldboard plowing. A decision was made that chisel plowing could not be introduced to farmers until further research, that went beyond the scope of the project, had been carried out to solve these problems.

(c). ***Recommendations***. Further research is necessary, particularly on the long-term strategy of reduced tillage to improve soil structure, the necessary management of organic matter in the reduced tillage system, and weed control. However, this area

does not appear to hold much potential for immediate pay-off, and perhaps should not receive high priority in an FSR agenda.

4.2.2.2 Precision Deep-Rip

(a). ***Justification.*** The term "precision deep-rip" (PDR) here refers to systems which use a type of chisel plow to "rip" open lines in the soil to a depth of 40 to 75 centimeters with cultivation carefully confined to this line. In some countries deep-ripping has also been called "sub-soiling". Crops are then planted on top of these "rip lines" and traffic is restricted to the inter-row space. The objective behind PDR is to open the soil to a depth to allow moisture from rainfall to penetrate deeper into the soil. At the same time, it is hoped that this will have the effect of concentrating rainfall in the rip line, and allowing plant roots to penetrate more deeply into the soil. The theory, then, is that PDR should concentrate rain water in strips, where it is stored at a depth that will prevent evaporation. At the same time it should aid plant root growth down to the stored water, and thereby increase crop yields.

Although the system is not appropriate for small-scale farmers at present, there has been much interest in the system from various development agencies and entrepreneurs. ATIP has undertaken research on the system in response to these interests.

(b). ***Results And Conclusions.*** Various PDR systems have been tested at the field level by the ATIP staff (Table 4.6).

In two trials in Mahalapye, a pre-plowing deep-ripping operation that was not part of a precision system showed some marginal positive effects on grain yield. In six other trials, PDR showed no positive effects on grain yields when compared with other "improved" treatments in the same trial.

A major problem occurred with weed control in a number of trials because of the lack of tillage between the rip lines. Recently some better weed control systems have been devised, but in many of the earlier trials, hand weeding was shown to require 200 to 300 person-hours per hectare. In later years, a large ripping implement was used. This created problems because none of the tractors in the village were capable of lifting the implement off the ground -- due to the height of the machine -- let alone pull it through dry soil. Farmers required larger tractors to use this particular piece of equipment.

While the theory behind PDR is sound, a practical implementation system for the farm level is still lacking. Improved weed control systems and practical equipment still need to be developed. Even if they were developed, this would remain a fairly complex technology, suitable -- at a minimum -- for farmers with excellent managerial skills and access to considerable resources -- for example, tractor draft power.

Aside from the question of practical implementation systems, PDR has not shown any evidence of being more productive or economic than a number of other, more conventional, tillage planting systems in recent years. In tests at 12 locations over the last three years PDR generally resulted in poorer yields than other systems [Persaud, 1990].

(c). ***Recommendations.*** The PDR system has been tested on-farm through the National

Tillage Trial since the 1988-89 season. This testing should be continued for a total of three to four years. This is necessary because of assertions that benefits are not obvious until the third year. If PDR does not show promise by the end of that period, it should then be dropped from the on-farm trials, so that resources can be concentrated on more promising systems.

4.3 TILLAGE ISSUES[9]

4.3.1 TILLAGE AND PLANT ESTABLISHMENT

4.3.1.1 Justification

At the beginning of ATIP work, plant establishment was suggested as a technical constraint in crop production and the importance of this issue was discussed with farmers during the exploratory surveys. Generally, farmers recognized the need for more reliable plant establishment, but the importance of this physical constraint was perceived to be no greater than other constraints such as yellowing of plants and pests [ATIP RP 2, p. 51].

A decision to address the problem of stand establishment still appeared justified when observing what transpired during the subsequent seasons. Conventional broadcasting seed and single plowing gave a highly erratic establishment in trials work, as well as under the farmers' own operations. The conventional system gave from zero to 27 percent field emergence in 56 sorghum plots of an RMRI trial [DAR, 1988, pp. 92-94] with an average of 10.8 percent and a standard deviation of more than 8.0. This meant that stand densities in nearly one-half of the conventional system plots in this trial were either below or above a wide target range of 20 to 60,000 plants per hectare. This was with a seeding rate, that was typical for farmers in the area, of six kilograms per hectare. Establishment in farmer implemented trials was also erratic. In one set of farmer implemented trials, the conventional system gave percent emergence averages of 4.2 percent to 10.8 percent depending on the target planting moisture [ATIP RP 1, p. 179]. When low emergence and variation were combined with typical seeding rates of 100 to 400,000 seeds per hectare, it was clear that the minimum and maximum plant establishment gave excessively low and high plant stands. Furthermore, when plant establishment was a major production constraint, it also affected other production factors that were related, such as water use efficiency by the crop, and weed control after canopy establishment.

Thus it was felt that stand establishment, even with sorghum which is notorious for poor establishment, was a problem that could be immediately addressed in the testing program.

4.3.1.2 Results And Conclusions

Plant establishment has been measured in most of the research managed tillage and planting method trials conducted by ATIP. In a few instances, the percent field emergence [ATIP RP 3, p. 166] was reported instead of plants per hectare.

The effect that tillage had on plant establishment is summarized below:

(a). Work on plant establishment initially consisted of evaluating various planting

[9] See Table 4.7 for details of ATIP work relating to tillage and planting systems issues.

TABLE 4.7: ATIP ACTIVITIES RELATING TO TILLAGE ISSUES

MAJOR FOCUS	MORE DETAILS	YEAR[a]	AREA	SAMPLE[b]	TYPE[c]	TRIAL	ATIP PAPERS		
Tillage and plant establishment	Steps in technology	1983-4	F'Town	2,3	Trial	RMFI	RD 84-1, p.8.23-8.25	RD 85-1, p.8.37-8.40	WP 5, p.10-11
	Maximum production	1983-4	F'Town	1,6	Trial	RMFI	RD 84-1, p.8.20-8.23	RD 85-1, p.8.5-8.11	WP 5, p.6-7
	Tillage and planting	1984-5	Mahal.	7,31	Trial	RMFI	RD 85-1, p.7.34-7.38 DAR 1987, p. 90	RD 86-1, p.59-62	RP 1, p.174-181
	Commercial steps in technology	1984-6	Mahal.	4,5,5	Trial	RMRI	RD 85-1, p.7.26-7.30 DAR 1988, pp. 92-94	RD 86-1, p.54-57 DAR 1987, p.109	RD 87-1,pII.37-39
	Tillage systems	1986	F'Town	2	Trial	RMRI	RD 87-1, p.II.68-70	PR F87-8, p.5-6	
	Water conservation systems	1986	Mahal.	3	Trial	RMRI	RD 87-1, p.II.35-37	DAR 1987, p.101	
Tillage and weed control	Double plowing	1985-6	Mahal.	31,14	Trial	RMFI	RD 86-1, p.59-62	RD 87-1, p.II.44-47	MP 87-9, p.6
	Double plowing	1985-6	F'Town	4,5	Trial	RMFI	RD 86-1, p.98-100 MP 87-7, p. 6	RD 87-1 p.II.70-72	PR F86-3 PR 87-5
	Commercial steps in technology	1984-6	Mahal.	4,5,5	Trial	RMRI	RD 85-1, p.7.26-7.30 RD 87-1, p.II.37-39	RD 86-1 p.54-57 MP 87-9, p.4	
	Tillage systems	1986	F'Town	2	Trial	RMRI	RD 87-1, p.II.68-70	PR F87-8, p.5-6	MP 87-7, p.3
	Water conservation systems	1986	Mahal.	3	Trial	RMRI	RD 87-1, p.II.35-37	MP 87-9, p. 4	
Tillage and land type interaction	Interaction and water infiltration	1985-6	Mahal.	3,3	Study	RMRI	EP 89-4, p.177		
	Interaction and seed emergence	1984-6	Mahal.	4,5,5	Study	RMRI	DAR 1988, p.92-94		
	Commercial steps in technology	1984-6	Mahal.	4,5,5	Trial	RMRI	RD 85-1, p.7.26-7.30 RD 87-1, p.II.37-39	RD 86-1 p.54-57	
	High potential site	1986-7	Mahal.	5,12	Trial	RMRI	RD 87-1, p.II.24-26 DAR 1988, p.107-108	RD 88-1, p.44 EP 89-3	
	Tillage by land type categories	1983-7	Mahal.	71	Trial	RMFI	EP 89-4	MP 88-6	
Tillage and fertilizer interaction	Phosphate superimposed	1983	Mahal.	13	Trial	RMRI	RD 84-1, p.7.32-7.33	RP 1, p.174	
	Maximum production	1983-4	F'Town	1,6	Trial	RMFI	RD 84-1, p.8.20-8.23	RD 85-1, p.8.5-8.11	WP 5, p.6-7
	Commercial steps in technology	1984-6	Mahal.	4,5,5	Trial	RMRI	RD 85-1, p.7.26-7.30 DAR 1988, pp. 92-94	RD 86-1, p.54-57 DAR 1987, p.109	RD 87-1,p.II.37-39
	High potential sites in dry season	1986	Mahal.	5	Trial	RMRI	RD 87-1, p.II.24-26	DAR 1988, p.107-108	
	High potential sites in wet season	1987	Mahal.	12	Trial	RMFI	RD 88-1, p.44	EP 89-3	
	Row planting plus fertilizer	1985,88	Mahal.	2,8	Trial	RMFI	RD 86-1, p.60-62	RD 89-1, p.52	

a. The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season, and 1984-5 refers to both the 1984-85 and 1985-86 cropping seasons.

b. Refers to the number of sites or farmers. RMRI trials will usually have more than one replication at each site. Figures in the column separated by a comma indicate sample sizes in different years.

c. This can refer to a study, survey, trial or paper.

methods. It became clear that the best way to address this issue was to look at the tillage and planting method in combination [DAR, 1984, pp. 176-180]. Therefore, nearly all ATIP work in this area has been carefully defined by both the tillage system and planting method used.

(b). From the work that was done on tillage and planting methods, the most commonly tested systems were ranked, in Table 4.8, in terms of the percent of seed sown that was established.[32],[33]

TABLE 4.8 A COMPARISON OF SEED EMERGENCE OR PLANT ESTABLISHMENT ACHIEVED UNDER DIFFERENT TILLAGE AND PLANTING METHODS

TILLAGE/PLANTING METHODS	AVERAGE DEVIATION FROM TRADITIONAL	NUMBER OF SEASON/ LOCATIONS
Early plowing + cultivation or double plow + row plant	+ 164.7 %	19
Early plowing + row planting	+ 149.3 %	33
Conventional plowing + row planting	+ 148.8 %	16
Double plowing/broadcast system	+ 29.6 %	62
Traditional single plow broadcast system		
Deep ripping	62.7 %	6

For some of these systems, special conditions for obtaining the best establishment were observed [DAR, 1988, pp. 92-94]. Row planting on the day of plowing did well on sandy soils, even when conventional single plow/broadcasting did poorly. Poor conditions in this situation were thought to be mostly due to low soil moisture. The same row planting system on loamy soils did poorly under the same conditions, but did well with better conditions. Early plowing plus row planting and double plowing, both providing improved moisture conservation before planting, proved to be better than the conventional system on all soil-types. Establishment under the deep-rip system was consistently poorer than any other system tested. All systems were observed to give better plant establishment with good soil moisture at planting.

(c). A wide range in plant establishment (i.e., stand density and percent emergence) was reported for each of the systems tested. The range of results for even the best systems was, in fact, greater than the differences found between the average establishment of various tillage and planting systems [DAR, 1988, pp. 92-94; ATIP PR F87-8, pp. 5-6]. The emergence percentage average and variability for all the systems raised the issue of whether useful seeding rate recommendations could be determined. Generally, farmers seeded according to a poor establishment scenario. Work in ATIP utilized the strategy of seeding according to a good emergence scenario [ATIP WP 5]. To consistently achieve 60 percent field emergence in

[32]. In cases where the percent emergence was not reported, it can be inferred from the plant establishment count, if seeding rates for different systems are the same.

[33]. The trials used in the ranking process were: Commercial Steps in Technology Trial, Francistown, [ATIP WP 5, pp. 10-11]; Maximum Production Trial, Francistown, [ATIP WP 5, pp. 6-7]; RMFI Trials on Tillage and Planting, Mahalapye [ATIP RP 1, pp. 174-181; DAR 1987, pp. 90]; Commercial Steps in Technology, Mahalapye [DAR, 1987, p. 109; DAR, 1988, pp. 92-94]; Water Conservation Systems' Trial, Mahalapye [DAR, 1987, p. 101] and Tillage Systems Trial, Francistown [ATIP PR F86-5, p. 4; ATIP PR F87-8, pp. 5-6]

sorghum,[12] a farmer in Botswana would need to use an improved system and target planting to good soil moisture, more effectively than was accomplished during trials work.

(d). The importance of plant establishment on grain yield can be seen in trial results, particularly in trials where some plantings gave exceedingly poor establishment [ATIP WP 5, pp. 6, 10]. It has not been possible to establish clearly the relationship between plant stand and grain yield on farmers' fields for cases where plant establishment was at a more useful level, that is, a minimum of 5 to 7,000 plants, per hectare [DAR 1987, pp. 231-233]. No trials have been conducted by ATIP specifically designed to investigate the relationship of plant density to grain yield. ATIP researchers have accepted the notion that a broad target range of plant populations is more practical for farmers than a specific plant population recommendation, in part because the optimum plant stand will depend on the amount of post-planting rainfall, and even poor stands can compensate considerably under favorable conditions

(e). Farmers have suggested that plant density tends to be self-correcting. It was observed that when initial establishment was low, the delayed emergence of seed still in the soil could establish and produce a successful crop. With excessive plant numbers, thinning of the smallest plants took place through competition under moisture stress and, if subsequent rainfall were favorable, the stand could still be successful. The ratio of harvest plant counts to emergence plant counts for different tillage and planting systems tended to support the idea of compensation [ATIP RP 1, p. 179]. The ratio seemed to be higher when the initial establishment was low and smaller when establishment was high.

It has been suggested that plant density compensation may be useful in the conventional broadcast single plowing system where a large excess of seed is sown, while it may be less useful in tillage and planting systems where more attention is given to planting under good soil moisture conditions.

(f). In some ATIP trials, it appeared that the effect of tillage and planting systems was primarily on plant establishment and the effect on grain yield was evident by the variation in plant numbers [DAR, 1984, p. 180]. However, this clearly wasn't always the case. INTSORMIL established a trial, at the request of ATIP and other DAR researchers, to investigate why there was a benefit from double plowing. In their study, the benefit of double plowing over single plowing was to increase soil moisture at planting, emergence percentage and early plant vigor. This benefit was most apparent on heavier textured soil. Grain yield was best correlated with early plant vigor and not plant numbers [DAR, 1987, p. 81; DAR, 1988, pp. 89-91].

These results bring into question the use of established plant counts as a measurement of tillage and planting method benefit, instead of the alternative of using an estimate of seedling vigor, or a combination of both. The establishment counts have been made approximately 45 days following planting. This measurement provides information on emergence and survival to this stage but does not indicate the relative vigor of these plants. It is, of course, possible to estimate the final plant population at harvest [ATIP RP 3, p. 171; ATIP WP 33].

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[12] Satisfactory field emergence in sorghum for more equable production environments is 60 percent or more. This is derived from expected plant stands and suggested seeding rates [Martin, Leonard and Stamp, 1976, p. 397, 1037].

4.3.1.3 Recommendations

Some recommendations arising out of the work that ATIP has carried out are as follows:

(a). Several tillage and planting systems have been found to improve plant establishment and should be recommended to farmers (see Section 4.2.1.2).

(b). Farmers must be prepared to target planting to good soil moisture if they wish to improve stand establishment generally, and particularly, if they are investing in new and more costly tillage/planting systems. ATIP has tested implementation strategies that would help farmers achieve this objective. These strategies involve using days with poor soil moisture to prepare land for later planting. Strategic type work has been emphasized with respect to double plowing [ATIP PR F89-1; ATIP PR F90-3; ATIP RP 1, pp. 175-177], row planting [ATIP RP 1, pp. 175-177] and farmer training on row planting [ATIP WP 29, pp. 7-9]

(c). Once farmers are successfully targeting planting to good soil moisture, they should assume that emergence will be good and adjust seeding rates accordingly. Seeding rates expecting 30 percent emergence from broadcasting and 50 percent from row planting are suggested [ATIP RP 3, p. 157]. In training on row planting, farmers have been advised to use hole number 9 or 10 of the Sebele Standard Planter and to block every other hole on the seeding plates of other planters for sorghum seeding. Farmers inexperienced with row planting tend to overseed.

4.3.2 TILLAGE AND WEED CONTROL

4.3.2.1 Justification

Before ATIP began, several studies had been conducted in which the effects of varying the number and the timing of weedings within the cropping season were compared [DAR, 1979, pp. 32-34; DAR, 1978, pp. 5-9]. The results from these studies were not conclusive, other than the fact that some weeding was beneficial for the grain yield outcome. ATIP evaluated these results and felt that what farmers reportedly did on their own, might be the best way of utilizing the labor that was being invested in weed control. It was decided, however, to investigate the recommendations of early weeding and multiple weedings in the ATIP program.

ATIP researchers decided not to investigate the use of herbicides on farmer's fields. This decision was made for three reasons:

(a). The cost of herbicide used would not likely be offset by benefits given the existing low level of grain yield achieved by farmers.

(b). The management required for the correct use of herbicides would be difficult for many farmers. The incorporation of pre-emergence herbicides on sufficiently moist soils would be a problem for farmers who already experienced tillage constraints and a limited number of days to do field work.

(c). The general application of herbicides by untrained persons could be socially and environmentally hazardous, particularly where the population often relied on unprotected water sources.

Selective post-emergence herbicides are costly and hand weeding would still be required to remove weeds not affected by the chemical. Non-selective herbicides require careful application and are costly. At the request of EFSAIP, ATIP did test a hand held weeder wiper, with wick applicator, using the non-selective glyphosate [EFSAIP, 1934, p. 322].

EFSAIP observed that farmers took the tactic of controlling weeds for the benefit of the current crop only. If the current crop were of little value, no investment was made in controlling weeds [EFSAIP, 1984, p. 320]. EFSAIP farmers felt that a single hand hoe weeding was all that was necessary. Hand hoe weeding was slow,[11] was usually only done once, and generally not over the entire field [EFSAIP, 1984, p. 317].

EFSAIP recommended a shift to year around weed management. A management scheme involving autumn and spring moldboard plowing greatly reduced weed seed. If the post-harvest tillage were timely and spring plowing were early, most weeds could be destroyed before the seed was set. In the long-term this would reduce the weed burden of a field [EFSAIP 1984, pp. 317-313]. EFSAIP, however, concluded that many farmers would find it difficult to implement this scheme in most seasons and, in some seasons, the rainfall pattern wouldn't permit farmers to do the post-harvest tillage [EFSAIP, 1984, pp. 319-320; ATIP RP 1, pp. 146-147]. A more manageable alternative of two moldboard plowings in the spring for general weed management was recommended [EFSAIP, 1984, p. 323].

Concern was also given to weed growth problems resulting from interventions. Alternative tillage systems such as chisel plowing were found to be less effective in controlling weeds than conventional plowing. It was also noted that early plowing without additional tillage before row planting, can increase weed control problems. Uncultivated strips and importing fresh kraal manure can also increase weed growth on the field.

Mechanical weeding following row planting could benefit weed control in two ways. This method can provide a tremendous savings in labor. Two individuals operating an animal drawn cultivator can weed an area in one-third the time as when weeding by hand [ATIP PR G90-2, p. 4]. Because weeding is more rapid and easier, more weedings are possible. Early weeding, which is the most effective in controlling weeds, is more feasible. However, farmers have been reluctant to adopt mechanical weeding [EFSAIP, 1984, p. 323].

Two particular weeds had been identified as major problems, and were dealt with more intensively by other DAR researchers. These weeds were Cynodon dactylon and witchweed -- Striga asiatica on sorghum, and Alectra vogelii on cowpea. Plowing plus harrowing to remove debris, or double plowing with an appropriate interval between the two plowings, have been suggested to help in the control of Cynodon dactylon [DAR, 1987, pp. 183-206; DAR, 1988, pp. 168-182].

4.3.2.2 Results And Conclusions

Baseline information on weed problems in the research areas, and typical weed control practices, has been collected in various surveys and studies. The purpose for collecting this information was to aid in the design of new interventions. A summary of the major results is as follows:

(a). ***Description Of The Weed Problem.*** The composition of the weed burden in most

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[11]. Using figures from a number of studies for weeding broadcast plots, a median value of 47 person-hours per hectare has been suggested [ATIP PR G90-2].

fields was highly variable. Lists of major weed species are given elsewhere [ATIP RD 84-1, pp. 7.23-7.25; ATIP RD 88-2, pp. 39-40]. In the Mahalapye area, broadleaf species that were the most common and caused problems for arable agriculture were motswalakoro (Sida cordifolia), motantanyane (Ipomea and Convolvulus spp.), khonkhorose (Acanthospermum hispidium), and mothomaganyane (Sesamum triphylum). Major grass problems were Urochloa spp., rathathe (Eragrostis rigidior), seloka (Aristida spp.) and pilato (Tricholena monachne). The incidence of T. monachne was observed to be increasing rapidly in both Shoshong and Makoro. Grass species were reported to pose the major weed problem on fields by farmers in the Francistown research area [ATIP PR F86-2, p. 6]. Several weeds occurred in abundance late in the season but were not considered to be a major problem in crop production. A number of weed species that were abundant or dominant on fields in other parts of the country included mothwa (Cynodon dactylon), mokhure (Datura spp.), thepe (Amaranthus spp.), and serepe (Portulacea oleracea) were found on a limited scale in the ATIP areas. The occurrence and importance of witchweed species was field-specific with a majority of the fields not seriously affected, at the time of the study.

The pattern of weed growth throughout the season varied depending on rainfall, plowing dates, and over winter grazing. Typically, following grazing by livestock during the winter months, the early spring weed cover of the land was low. After rains began and before plowing took place, weed growth was sometimes dramatic. In farm monitoring during the period from 1982-85, ground cover by weeds on unplowed land reached an average of 50 percent by the middle of December [ATIP MP 87-4, p. 176; ATIP MP 87-14, p. 1]. Yet, by this time, only 40 percent of the land that was to be plowed and planted, had been plowed for the first time. This meant that in the farmer's own operations, weed growth prior to the first plowing of the land constituted a serious problem. Soil moisture was lost and subsequent plow/broadcasting was impeded. The problem of late plowing and pre-plowing weed growth was most severe for farmers who hired traction.

Following conventional plow/broadcasting, the amount of weed growth varied with rainfall and the level of plant establishment. The high percentage of weed cover before plowing compared with averages from 1.8 percent to 21.1 percent at post-plant weeding time for conventional plow/broadcasting in different ATIP trials [ATIP MP 87-9, pp. 4-6].

(b). ***Weed control By Farmers.*** Weed control by farmers was made up of two main elements: plowing at planting time and a hand hoe weeding done after the crop was well established.

i. ***Conventional Plowing For Weed Control.*** Generally, weed control was effective if the single plowing were of a high quality and was followed by good plant establishment. To achieve quality plowing usually required that there be a moderate level of soil moisture. On dry soils, the plowing was sometimes not deep enough, therefore the inversion of the soil was not complete, and the weed cover, as a result, was not turned under. In the rather dry 1983-84 season, farmers in the ATIP Mahalapye area rated more than 40 percent of the area plowed to be on dry or drying conditions [DAR, 1985, pp. 188-189].

The effectiveness of plowing to control weeds was also affected by the level of pre-plowing weed growth (see (a) above). By mid- to late-season the weed growth before plowing was sometimes heavy. Not only did these

weeds dry out the soil, but many survived the plowing and increased the weed burden.

ii. ***Conventional Hand Hoe Weeding.*** Hand hoe weeding and the amount of labor required for this activity has been one of the principal measurements made by ATIP on the farmer's own cultivated land, as well as in trials work. A number of facts about typical hand hoe weeding are summarized elsewhere [ATIP MP 87-14, pp. 1-9]. The number of days interval between plow/broadcasting and hoe weeding varied considerably. Averages from 40 to more than 60 days were reported. The average interval was far longer than the recommendation for good sorghum production. During dry seasons, less than two thirds of the farmers' plots that were monitored, were weeded. During the drought, most of these unweeded plots were planted late, had poor plant establishment, or for some other reason showed little potential to produce a useful grain harvest. The lack of labor was also cited as a reason for not weeding. The recommendation of multiple weedings and early weeding after plowing were not generally practiced by farmers [ATIP RP 2, pp. 51-52; ATIP RP 1, pp. 69-72].

In subsequent seasons with higher rainfall, ATIP observed that large areas, with good potential to produce a harvest, were often left unweeded. In this situation, the lack of labor appeared to be most important. Weeding is a practice that is contingent on circumstances.

Weeding labor input was low during dry seasons [ATIP RP 2, pp. 42-47; ATIP MP 87-14, p. 3]. Average weeding time was from 25 to 35 person-hours per hectare. It is assumed that in wet seasons, the average would increase from 35 to 50 person-hours per hectare. Weeding times for conventional plow/broadcasting in trials ranged from an average of five person-hours per hectare in one village-season [ATIP MP 87-9, p. 6] to more than 100 person-hours per hectare in one RMRI trial [ATIP PR F86-5, p. 5].[14]

Because weeding time is a function of the level of weed burden, two prediction equations for weeding labor have been made using the weed burden assessment. The first equation [DAR, 1987, p. 90] was based on researcher controlled weeding and predicts an average weeding time from weed cover only. The second equation [ATIP MP 87-14, p. 3] was from farmer controlled weeding and included variables related to circumstances that influenced the weeding activity in addition to weed cover.

Household members spent only about four hours per day on weeding [ATIP MP 87-14, p. 4]. Most of this time was in the early morning or late afternoon. This observation led to the conclusion that households were reluctant to make a major investment in weeding. Farmers also indicated that a relatively narrow time window for weeding existed for any given area [ATIP MP 87-14, pp. 5-6]. Beginning late with weeding meant that it sometimes clashed with bird scaring operations. With the dramatic shift to

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[14]. It is virtually impossible to derive a standard time for the weeding operation since it will depend on the quantity, size and composition of weeds, soil-type, moisture conditions etc. A suggested standard time, subject to the above caveats, has been given as 47 person-hours per hectare for broadcast plots [ATIP PR G90-2]. However, as will be seen in this report, several different times for weeding have been estimated.

tractor hired plowing, large areas of fields were plow/broadcasted at one time. With the tendency to minimize weeding input and the narrow time window for finishing weeding, the result was that household labor was not able to cope with the weeding. As household members who traditionally assisted with weeding left, the weeding problem became worse. The weeding problem was also made worse when the number of hectares put into cultivation was increased.

Weeding labor was provided primarily by adult women of the household. Secondary sources of labor were children, adult men and non-household members [ATIP MP 87-14, pp. 4-5; ATIP RP 1, pp. 72-76]. Weeding was one way of capitalizing on available female and child labor which had a low opportunity cost compared with that of men [ATIP MP 87-14, pp. 4-5]. In the conventional system, the weeding labor of women and children could not be utilized productively in dry years. However, in the more productive years, weeding labor became a constraint to production in many households.

(c). ***Weed Control Interventions.*** A number of weed control interventions or other experimental treatments that affect weed control have been assessed in the ATIP program. Results from these can be summarized as follows:

i. ***Hand Hoe Weeding Interventions.*** Extra weedings were included or proposed as treatments in several of the earlier ATIP trials [ATIP RD 83-1, p. 8.20, 8.32; ATIP RD 84-1, p. 7.41, 8.37, 8.5]. In every situation, the treatment was not implemented, or the second weeding was not necessary [ATIP WP 5, p. 4, 10; ATIP RD 84-1, p. 74]. In subsequent research, the effect of multiple weedings was no longer tested. This decision was made because:

-- Farmers perceived that there was adequate control and that additional weeding labor input was not profitable.
-- Trial results showed that multiple weeding was often not necessary.

ii. ***Hand Held Weed Wiper Using Glyphosate (Round-Up).*** An informal assessment of the weed wiper was made by researchers and a few farmers during the 1983-84 season at Mahalapye. This activity was not reported in project documents. It was observed that the weed wiper was inappropriate for young seedlings, the wick soon became dirty and the flow of herbicide was stopped. On heavy weed stands, it was difficult to know where the herbicide had been applied. After a period of time in which the systemic chemical could kill plants, it was observed that many plants escaped. Even with the best coverage, follow-up hand hoe weeding was still required. ATIP reported to EFSAIP that use of this equipment would be difficult and costly for farmers [EFSAIP, 1984, p. 322].

iii. ***Weed Control In Various Tillage/Planting Systems.*** In the research on tillage and planting methods, the primary focus was on ways to improve yield returns. However, the level of weed control achieved under each method was generally compared with that of conventional single plow/broadcasting checks. Most of the results from this work are summarized elsewhere [ATIP MP 87-7; ATIP MP 87-9]. From this work, tillage and planting systems can be

ranked in terms of the level of weed control that they provided.[15],[16] Ranking of these systems is given in Table 4.9.

TABLE 4.9 A COMPARISON OF WEED CONTROL ACHIEVED UNDER DIFFERENT TILLAGE AND PLANTING METHODS

TILLAGE/PLANTING METHODS	AVERAGE DEVIATION FROM TRADITIONAL	NUMBER OF SEASON/ LOCATIONS
Double plowing/broadcast system	- 29.0 %	70
Traditional single plow/broadcast system	-	--
Early plowing + cultivation or double plow + row plant	+ 10.1 %	14
Chisel plowing + row planting	+ 288.9 %	3
Early plowing + row planting	+ 318.6 %	14
Strip cultivation, with fallow strips uncultivated	+ 353.4 %	5
Deep ripping	+ 669.9 %	6

Conclusions that were drawn about how these tillage and planting systems affected weed control were as follows:

-- Double plowing sometimes improved the control of weed growth. Even when weed control was not improved, double plowing resulted in a larger percentage increase in grain yield than the percentage increase in weeding labor required.

-- A system of early plowing and later row planting was ideal for farmers who were able to cultivate or double plow just before planting, if weed problems appeared.

-- Early plowing plus row planting was also observed to increase grain yield, but excessive weed problems could restrict early crop development and grain yield in about one-half of the plantings during seasons with relatively poor rainfall.

-- The capability to mechanically weed soon after planting would aid in the control of weed problems. For farmers with no access to cultivator resources, the early plowing and row planting system is risky.

-- Tillage systems involving deep-ripping must also include a practical and cost effective weed control component before they can be used as a general extension recommendation.

The ranking in Table 4.9 does not fully reflect the impact the systems had, or

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[15]. In cases where the percent groundcover by weeds, at traditional weeding time, was not reported, the comparison with the traditional system was made on the basis of the respective weeding labor times recorded in person-hours per hectare.

[16]. The ranking is based on results from the following trials: RMFI Double Plowing Trials, Mahalapye [ATIP MP 87-9, p.6]; RMFI Double Plowing Trials, Francistown [ATIP MP 87-7, p.6]; Commercial Steps in Technology Trial [ATIP MP 87-9, p. 4]; Tillage Systems Trial [ATIP MP 87-7, p.3] and Water Conservation Systems' Trial [ATIP MP 87-9, p.4].

could have on weed control throughout the entire season. Three other considerations are important in addition to the weed burden at weeding time. These are as follows:

- The effectiveness in controlling weeds early in the season.
- The effectiveness of the system to establish plants which leads to weed control benefits through the entire cropping season.
- Whether row planting, which provides the potential for mechanical weeding, is used.

A summary of various effects that different tillage and planting systems had on weed control is given elsewhere [Table 8 in ATIP MP 87-9, p. 7].

iv. ***Use Of Kraal Manure***. Some farmers have indicated that they feel that the use of kraal manure will lead to increased weed problems on their field [ATIP RP 1, pp. 70-71]. Relatively little work has been done, to date, on the use of kraal manure [ATIP RD 89-1, pp. 53-54; ATIP RD 85-1, p. 7.33; ATIP RP 1, p. 199] but one important trial is on going. Thus far, the effect of manuring on sorghum growth and yield has not been significant [ATIP RD 89-1, pp. 53-54]. Effects on weed burdens have not been observed, but these data are not yet analyzed. Manure applied in these trials was generally aged and therefore should not contain many viable weed seeds. The technique of heaping fresh manure during the winter to kill weed seeds has been proposed, but has not yet been tried by ATIP.

v. ***Promotion Of Good Plowing Plus Row Planting And Mechanical Weeding Package***. The use of mechanical weeders have been noticeably absent from the ATIP research program. The main reason for this was the generally poor quality of row planting achieved under farmer management. This would have made mechanical weeding very difficult [ATIP RD 84-1, pp. 7.34-7.35]. As more emphasis has been shifted to the promotion of row planting, interest in mechanical weeding has also increased [ATIP RP 6, Section 2.2.1.3]. An approach pursued in ATIP was to upgrade the skills of farmers in row planting and mechanical weeding through farmer training [ATIP WP 29, pp. 5-10]. It was felt that not only was the development of skills important, but the use of a row planting and mechanical weeding package also required a change in management. Management changes such as earlier weeding than was customary, were presented at the farming training.

4.3.2.3 Recommendations

A summary of the recommendations is as follows:

(a). The current recommendations of weeding early and more than once, if necessary, should not be dropped. It is important to recognize, however, that most small farmers using hand hoe weeding will not follow this recommendation. This is particularly so as labor for weeding in the household becomes more limited.

(b). The emphasis on row planting and mechanical weeding should be continued and increased. This package can be promoted in various ways including farming training. In this promotion, several problem areas need to be addressed:

i. Because labor is becoming a constraint, even for the adoption of row planting

and mechanical weeding, men and older children at home should be systematically involved in training for these operations [ATIP WP 29, pp. 9-10]. In this way, a small labor force will be able to cope with weeding large planted areas.

ii. Another way to address the labor problem for mechanical weeding is to promote the use of cooperative weeding arrangements. This can apply to mechanical weeding. In this way, row planting and mechanical weeding could even be used by households with very limited labor, or without male labor. All participants need training.

(c). In research work, it is important to continue the evaluation of harnesses, hitching arrangements, and equipment for mechanical weeding. There is a need for further work on the development of light weight weeders pulled by a donkey (see Section 4.4.4). There are also questions about the benefits of harness arrangements in row planting, such as the wide spacing of the draft team, where donkeys walk on and mark the paths for row planting. This system should be compared with classical row markers as a means of providing rows that can be mechanically weeded.

(d). Research work needs to continue to identify and test weed control strategies for water conservation systems that do not create a weed free seedbed (i.e., the deep-rip system and strip cultivation system). This work should be handled in an RMRI format.

(e). There is a need to evaluate the immediate and long-term effects of leaving a weed cover on strips in fields. These weed strips might have benefits for water run-off control and soil erosion control. They have been included in some of the rainfall run-off management work. Effects of these weed strips that need evaluation are:

i. Encroachment of weeds into neighboring cultivated areas.
ii. Harboring of crop pests.

These problems have been cited as being potentially serious by farmers.

4.3.3 TILLAGE AND LAND-TYPE INTERACTION

4.3.3.1 Justification

In the surveys and exploratory work that ATIP used to establish research priorities, there was no indication that farmers' management of the land varied with the different soil-types. This may have been because the differences between soil-types that were cultivated were somewhat subtle. More extreme soil-types such as sandveld sands and black cotton clays were not found in the areas, or were not cultivated by the farmers. Detailed characteristics for soils of several fields, that have been part of the ATIP research program, are reported in several places.[17]

ATIP trials have generally not been designed to test tillage and land-type interactions. Often, where a trial included sites with contrasting soil- or land-types, other differences such

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[17]. See, for example, Mays and Price [1987], in which detailed results of physical and chemical analyses of soil samples are presented from Makwate [pp. 33-37], Shoshong [pp. 38-42], Makoro [pp. 43-47], Marapong [pp. 74-83], and Mathangwane [pp. 84-88]. Other useful references are ATIP RP 1, pp. 154-166, 172 and DAR 1987, pp. 109-113.

as date of planting and rainfall patterns were confounded with the soil-type difference effect on cropping outcomes. Unfortunately, in a majority of the reports from ATIP experiments, the soil-types of trial sites were not given.

Even with this disclaimer, where testing has been conducted on a sufficient number of sites or season-site combinations, for which soils have been classified, interactions can be evaluated. This brief summary covers both tillage system by land-type interactions as well as the effect of land- or soil type on production, under a single system.

The objectives for evaluating these interactions were to:

(a) Determine whether a tillage - or tillage-planting - system should be targeted for a particular soil circumstance

(b). Determine relative productivity potentials of land so that strategies for production could be planned accordingly.

4.3.3.2 Results And Conclusions

A summary of the results and conclusions, is as follows:

(a) Tillage was observed to improve rainfall infiltration on all soil-types. This effect was clearly observed, but was also measured on the basis of how deep the soil became wet in 1985-86 and 1986-87 [ATIP EP 89-4, p. 177]. Moldboard plowing and sub-soiling were found to increase the depth of rainfall infiltration by 35 percent over no tillage. Similar results were obtained for loamy sand, sandy clay loam and sandy loam soils. These results indicated that all soils in this range of texture compacted before the tillage period, and hence benefited from tillage.

(b). Tillage and planting methods were found to affect the percent emergence of seed somewhat differently on surface soils with varying textures, and under different planting conditions. In the analysis that was performed [DAR, 1988, pp. 92-94], emergence under the traditional single plow and broadcast system was used as an indicator of planting conditions.

i. When the surface texture was loamy, row planting -- on the same day as plowing -- improved emergence over single plow and broadcast, but this effect occurred when planting conditions were conducive to good emergence. Under conditions that generally resulted in poor emergence, this planting method failed more often than single plowing and broadcast. Early plowing before the day of row planting both increased the stability of the emergence response and the benefit of row planting under all planting conditions.

ii. When the surface texture was sandy, row planting -- on the same day as plowing -- gave a consistent 30 to 50 percent emergence almost regardless of the conditions. These results were observed during three seasons of drought. Early plowing did not significantly affect emergence on the sandier soils.

iii. No other tillage and planting method by soil-type interactions were observed. Under the broadcast system, double plowing consistently gave better percent field emergence than single plowing on all soil-types.

(c). Evaluating the effect of an interaction between soil-type and tillage on grain yield was more complicated. This complication was due to the large number of

determinant factors (for yield) that occurred during the crop growth period. Mostly, cause and effect relationships between tillage/planting methods, soil-type, and crop growth were evaluated in researcher implemented trials. Some of these are discussed below:

i. The effect of depth and clay content of the sub-soil (i.e., water holding capacity) with tillage was assessed in an RMRI trial on sorghum production factors. In this trial, every effort was made to target tillage and planting operations to good soil moisture. However, because traction types did not respond equally to planting opportunities -- either tractor, donkey or oxen were used on a site -- and some of the sites experienced severe drought during much of the planting season, a wide range of planting conditions, planting dates, as well as subsequent rainfall patterns during the growing season were represented [ATIP RD 87-1, pp. II-37-II-38].

Table 4.10 notes that deep to medium deep soils with a sub-soil clay content to hold infiltrating water, would probably give the best average return to double plowing in these types of seasons.

TABLE 4.10 INFLUENCE OF SOIL TYPE ON SORGHUM GRAIN YIELD AS A RESULT OF DOUBLE PLOWING, MAHALAPYE, 1984-87

SOIL TYPE	RANGE IN SOIL DEPTH	RANGE IN % VOL WATER	NOS SITES	GRAIN YIELD (KG/HA) DP[a]	SP
Deep medium textured	90-200 cms	9-19	8	692 ***	354
Shallow light textured	45-75 cms	5-9	6	266 **	316

Source: RMRI Commercial Steps In Technology Trial, 1984-86. References are listed in Table 4.7. Nine season locations, each including two replications.

a. *** denotes statistical significance for the difference in the comparison at a 0.001 probability level; n.s. denotes no significant difference.

ii. The economic benefit of any tillage or tillage-planting option will be improved if the option can be effectively targeted to appropriate soil- or land-types. This is important because some of the economic analyses indicated that the benefits of some tillage options were just at the margin of being profitable. Double plowing in this RMRI trial was not profitable when traction was costed at a hire rate [DAR, 1987, pp. 92-94], except for trials on deep soils with high water holding capacity and with good moisture for germination at planting. Double plowing on shallow soils or on poor planting moisture was not profitable.[18]

iii. When double plowing was compared with single plowing at high potential sites [ATIP EP 89-3; ATIP RD 6, p. 44], grain yield was not improved. A high potential site was an area of the field that the farmer, together with researchers, had identified as having the highest potential for grain yield in good and poor rainfall. Generally, these sites were at the lower end of the field with comparatively deep soil profiles and some water run-on during

[18]. In the reference [DAR, 1987, pp. 92-94], soil with high water capacity and good soil moisture was reported as Environment A, while Environments B, C, and D represented shallow soils or planting into poor soil moisture.

storms. Double plowing was tested as part of a tillage and fertilizer package to improve yield on targeted sites of fields with the highest potential for pay-off.

Testing on these sites was in one relatively dry and one very wet season. Average yields at these sites were high (an average of more than 500 kilograms per hectare and 1200 kilograms per hectare in the dry and wet seasons, respectively) which confirmed the potential of these sites. All plowing was done with a tractor in the dry season, and there were excellent planting conditions for both single and double plowing. Rainfall in the second year was twice the long-term average and this favorably affected planting conditions and crop growth throughout the entire season. Of interest was that all planting was completed early in the season. Under these circumstances, two possible explanations have been given why double plowing was not effective at these sites:

-- The first is that the sites were natural water receiving points. During rainfall, the water was naturally concentrated and infiltrated at these sites even before tillage. Thus the rainfall conserving effect of double plowing may have been masked.

-- The other is that plowing quality was highly satisfactory for both single and double plowing at these sites. Plowing conditions were good and planting was early enough in the season to capture most of the seasons' rainfall. The quality and earliness of plowing and planting may have been sufficient to achieve benefits that were sometimes otherwise obtained through double plowing.

A number of questions were raised as to what conditions were necessary to obtain the benefits from double plowing. Clearly, the capacity of the soil profile to hold added moisture in reserve was important. Additionally, the amount of rainfall before planting, moisture condition in the plow depth at planting, and other factors that contributed to the quality of plowing could also be important. Agronomists suggested that soil bulk density was also likely to be influenced by the type of tillage system used. Should double plowing be viewed as an improved practice for all farming operations or as a remedial action to compensate for single plowing that is of poor quality or poorly timed? The answer is unresolved, but surely lies somewhere between the two extremes. As for resource poor farmers, poor quality and poorly timed plowing is common. To help resolve technical issues related to tillage, a Soil Management Specialist was recruited to conduct research outside the realm of FSR.[19]

(e). Analyses were also performed on the relationship between soil, rainfall, tillage and the grain yield results from farmer implemented trials:

i. Data on soil characteristics were more sketchy, and the analysis was complicated by the way the tillage treatments were managed in this type of trial. For example, the condition of the plow and plowing depth were highly variable conditions that affected plowing quality, but were not included in the

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[19]. This individual was recruited under the Sorghum and Millet Collaborative Support Research Program (INTSORMIL) with partial support from ATIP.

analysis. Two regression analyses were reported, but the results were not particularly useful in clarifying tillage and soil-type relationships [DAR, 1987, pp. 89-96; ATIP RD 87-1, pp. II.44-II.45].

ii. A better explanation of how land type affects grain yield and the benefit from double plowing in the farmer implemented trials came from categorizing land-types based on position in the landscape, rather than looking at specific soil characteristics. These categories were not similar to the FAO soil classes in that the differences in these categories were subtle and generally related to position on the toposequence. Often, several land types were found within a single Soil Mapping Unit. These categories were initially developed using aerial photographs of the research areas.

In other reports [ATIP FP 89-4; ATIP MP 88-6], land type categories were defined. These land related circumstances were closely associated with variation in grain yield and to how well rainfall was utilized.

Land type categories and a brief description of how crops responded under farmer management on each type are as follows.

- ***Alluvial Flats.*** Clayey bottom land soils. Farmers had difficulty tilling these soils because the soil moisture window for operations could be very narrow. Grain yield and benefits from double plowing were low on soils in this position.

- ***Soils With Restricting Sub-soil Strata.*** These were shallow soils with limited water holding capacity. They were often located at the top of weather hill rises in the land scape. These soils were commonly farmed in the Mahalapye area, possibly because of their proximity to villages and the fact that the surfaces were generally sandy and easy to manage. Benefits from double plowing were low on these types of soils.

- ***Deep Loamy Sands.*** These soils were often found near the top of a toposequence on pediplains, below hills in the Mahalapye area. Even though the water holding capacity was low per unit depth, water holding capacity in the total rooting zone was sometimes quite good. These soils gave good crop growth during drought and also showed a surprisingly good response to double plowing under farmer management.

- ***Well Drained Lower Slopes Of Pediplains.*** Lower slopes and to a lesser extent middle slopes, showed good to excellent crop growth during drought, with a good response to double plowing under farmer management. These lower slope positions tended to have deep soils with higher clay content in the sub-soil than positions further up the toposequence. These positions also corresponded to the high potential sites.

Soils With Highly Uneven Surfaces. This was a variable land-type category that tended to have highly heterogeneous crop growth within plots during drought.

4.3.3.3 Recommendations

The ATIP research areas have, over the years, been found to represent a good range of soil and site situations. Based on the work undertaken to date, it is recommended that:

(a). Work on sandy sites, particularly those that are shallow, should focus on plant stand establishment, weed control and not on other moisture conservation techniques such as multiple tillage systems. Tillage for water conservation should focus on soil profiles that can store the water.

(b). Research should continue on tillage and planting methods to obtain a better statistical assessment of their interaction with soil-types.

(c). Some years ago, ATIP made the decision to develop and utilize the high crop production potential of the lower slope and water run-on sites. As a result of these decisions, work on identifying and testing production recommendations specifically for high potential sites was begun [ATIP EP 89-3, ATIP RD 88-2, p. 44]. Also, part of the Rainfall Run-off Management Study involved building water conservation terraces that emulated the natural high potential sites [DAR, 1988, pp. 107-108]. It is recommended that work directed toward increasing the productivity of high potential sites should continue.

4.3.4 TILLAGE AND FERTILIZER INTERACTION

4.3.4.1 Justification

Soils in the ATIP research areas which are commonly tilled are generally lacking in chemical properties necessary for high grain yields [ATIP RP 1, p. 157]. Some agronomists suggested that these soils were selected more for their physical properties which made them easy to manage, than for their fertility [ATIP RP 1, pp. 156-157]. With intensive year-to-year crop management, a physical and profitable response to fertilizer application on these soils could be expected in all but the driest seasons. The question, then, is whether responses to fertilizer would be profitable under traditional (conventional) management, or under the intermediate levels of management that are tested with farmers in the research program.

Fertilizer recommendations for the Mahalapye and Tutume areas were developed from a multi-location fertilizer trial conducted during the relatively wet seasons of 1969-72 [Jones, 1984]. It was recommended that 20 kilograms P per hectare be applied before plowing and planting sorghum on fields at Mahalapye, where good crop production practices such as early plowing and row planting were used. Phosphate fertilizer was not recommended for the Tutume area. In some areas of the country, nitrogen as a top dressing at about five to six weeks after emergence, was recommended but only when the crop stand was good and phosphate fertilizer had already been applied [Anon, 1980]. Though the benefit from nitrogen added to phosphate was significant, and apparently profitable at trial sites near Mahalapye in the 1969-72 trial [Jones, 1984], a top dressing of nitrogen was not recommended at either Mahalapye or the Tutume district. Because the vast majority of farmers working with ATIP did not use improved tillage and planting practices, the use of chemical fertilizer on their fields was not recommended.

ATIP has had an interest in research being conducted within DAR on residual benefits, in the following seasons, from the use of phosphate fertilizer. Such a benefit could greatly

increase the usefulness of phosphate for farmers who struggle with inter-year variability in rainfall, crop productivity, and need for fertilizer.

Early survey work indicated that few households in the ATIP research areas used chemical fertilizers [ATIP RP 1, pp. 67-68; ATIP RP 2, p. 41]. When asked to give their perceptions concerning improved practices, farmers ranked the use of chemical fertilizers very low [ATIP RP 1, p. 69]. Agricultural demonstrators, on the other hand, said that the use of fertilizer would be a promising change and could increase crop productivity [ATIP RP 1, p. 71]. The reasons they gave why farmers failed to use fertilizer were: that they lacked funds and knowledge, and were fearful of increased weed growth.

There appeared little justification in working with fertilizer application per se under farmer managed conditions. However, as the project moved increasingly in the direction of soil and water management through improved tillage and planting methods, justification for including fertilizer comparisons increased.

The objectives for including fertilizer comparisons were the following:

(a). To test whether fertilizer use was profitable and should be recommended to resource poor farmers who used improved practices.
(b). To assess the potential of improved tillage and planting practices by reducing the constraint of soil fertility.
(c). To demonstrate the value of phosphate application to farmers in the research areas and, in doing so, obtain their reactions.
(d). To obtain information on fertilizer use from farmers who used chemical fertilizer on their own.

The importance of fertilizer in ATIP research has been limited. Fertilizer was added to several tillage and planting method trials as a simple "with" and "without" comparison. No ATIP trial focused specifically on the use of fertilizer, except in the ROFGs where farmers, who were interested, were assisted in testing the effects of phosphate fertilizer on their own fields.

The fertilizer comparison usually involved applying phosphate at the rate of 20 kilograms of P per hectare, by broadcasting before plowing. Because 2:3:2 plus Zn was distributed to the farming community by ARAP in 1987, this complete fertilizer was used in the Row Planting and Fertilizer Trial. Nitrogen plus phosphate was also tested in the High Potential Site Development Trial. A list of trials with a tillage and planting system by fertilizer interaction is given in Table 4.7.

4.3.4.2 Results And Conclusions

A summary of the major results, and the conclusions derived, is given below:

(a) In the earliest test of phosphate fertilizer, fertilizer was superimposed on an early plowing block, with plowing and a number of different planting methods for sorghum implemented by farmers themselves. Researchers were confident that early plowing with later planting would result in improved soil moisture and crop growth. Improved tillage and planting methods were beneficial, but the effect of the fertilizer was not significant [ATIP RD 84-1, pp. 7.32-7.33; ATIP RP 1, p. 174]. With respect to the demonstration objective of the use of phosphate fertilizer, farmers were interested but expressed concern about the expense of fertilizer, even before the crop was harvested.

(b). In the Maximum Production Trial, a recommended production package for cereals including phosphate fertilizer, was implemented under researcher management. This package showed promise, but failed to consistently give a large yield benefit under the harsh growing conditions. In this trial, phosphate fertilizer was not profitable [ATIP WP 5, pp. 6-8].

(c). The Commercial Steps In Technology Trial included a recommended level of phosphate fertilizer comparison. Phosphate was tested in this RMRI factorial trial with several production factors for sorghum over three seasons, at five different sites. Generally, implementation and yield levels were good and there were several significant results [DAR 1987, pp. 109, 112-3].

The highest grain yield and the highest rainfall use efficiency were obtained for several tillage and planting systems when phosphate fertilizer was applied [ATIP EP 89-4, p. 182]. Even though the yield return to phosphate fertilizer was positive and significant, the economic return was not. A partial budget analysis for the general use of phosphate fertilizer in the conventional single plow/broadcast system showed a loss of P48.21 per hectare in this trial. Further analysis indicated a highly significant site by tillage and planting system by fertilizer interaction. When sites were grouped by soil-type, the results (Table 4.11) suggested a useful trend. The return to phosphate fertilizer was most significant and profitable with the best tillage and planting systems on soils with high water holding capacity [DAR 1987, pp. 93-94]. The response was assumed to be related to improved soil moisture and plant establishment.

TABLE 4.11: EFFECT OF PHOSPHATE BY TILLAGE AND SOIL-TYPE, MAHALAPYE, 1984-85

TILLAGE AND PLANTING METHOD	SOILS WITH HIGH WHC[a]			SOILS WITH LOW WHC		
	P KG/HA	NO P KG/HA	MARGIN[b] PULA/HA	P KG/HA	NO P KG/HA	MARGIN PULA/HA
Traditional single plow/broadcast	463	359	Loss	275	316	Loss
Double plowing/broadcast system	782	614	22.51	261	266	Loss
Early plowing + row planting	902	600	43.41	445	363	Loss
Early plowing + row planting	1017	711	44.68	472	323	Loss

Source: Commercial Steps In Technology Trial, Mahalapye, 1984-86. [ATIP RD 87-1, pp. II.37-II.39].

a. Water holding capacity as a function of soil depth and clay content in the sub-soil [DAR 1985-86, p. 111].

b. The partial budget based on added costs and benefits of using 20 kilograms of P per hectare. In this analysis, sorghum was valued at P0.39/kg and fertilizer and application labor at P62.89 per hectare.

Fertilizer comparisons were included in other trials when it was thought that the reliability of either soil moisture or plant establishment might be improved by some factor in the trial.

(d). Special sites with high production potential were identified. The production potential came, in part, from water run-on during storms and, in part, from deep soil profiles [DAR 1988, pp. 107-108; ATIP RD 87-1, p. II.24-II.26]. Sorghum production at these sites was good for a dry season even under farmer implemented broadcast and plowing. Under these conditions, the yield response to phosphate fertilizer was significant. The return to 40 kilograms of P per hectare was profitable, but it was considered doubtful that farmers would consider the purchase of this quantity of fertilizer even for selected sites.

(e). A somewhat modified production package was tested at selected high potential sites under good rainfall conditions the following season. What was noteworthy under these good moisture conditions, was the significant and profitable response to a nitrogen -- applied before plowing -- and phosphate combination [ATIP EP 89-3]. The response to phosphate alone was not significant, nor was there an interaction with a plowing treatment. The response to nitrogen when added to phosphate corroborated findings for Mahalapye in the 1969-72 fertilizer trial [Jones, 1984].

(f). Two trials, targeted to farmers who used row planters, included fertilizer comparisons [ATIP RD 86-1, pp. 60-62; ATIP RD 89-2, p. 52]. In both trials, fertilizer was added because it was felt that the improved plant establishment under row planting would increase the reliability of a return to the fertilizer. In the 1988-89 trial, banding of reduced rates of fertilizer was tested to determine if the cost could be reduced in a more precise application and plant establishment system. The use of phosphate fertilizer was expected to be more profitable with banding than with broadcast application [Martin, Leonard and Stamp, 1976, pp. 150-151]. In both trials, the results were agronomic failures. Benefits of fertilizer and of banding were not measurable. However, useful information was obtained on problems associated with row planting. Specific notable points were:

i. A major reason for the poor response to fertilizer was clearly the problem the farmers continued to have with plant establishment. Plant establishment under farmer management was not consistent enough to expect a response from banded fertilizer.

ii. Many planters were in poor condition which affected their performance. About one-half of the planters were equipped with a fertilizer hopper but none of these were found to be functioning correctly. It was observed that farmers tended not to maintain or shelter their planters in a satisfactory manner.

ii. ATIP researchers were also concerned with the precision of application -- placement and flow uniformity -- using the fertilizer attachment of the Sebele Standard Planter.

4.3.4.3 Recommendations

Recommendations for future work are as follows:

(a). ATIP has included simple fertilizer comparisons in trials that involved improved soil and water management systems. It is recommended this be continued for trials, with researcher management, that address the problems of soil and water management or plant establishment. The objectives of this work would be to determine long-term benefits from fertilizer use and to gain a better understanding of the interaction between soil- and land-type, tillage and planting system, and fertilizer.

(b). The Soil Water Management Group at Sebele should continue its on-farm fertilizer testing to aid in developing recommendations on the type and rates of fertilizer to use on different soils in the above trials.

(c). When testing the interaction of fertilizer with the tillage and planting systems, station-based research should also consider if fertilizer use is profitable under the

plant establishment achieved without gap-filling or thinning. Farmers are very reluctant to thin plant stands. So, results from trials that have been thinned may not be directly useful in making recommendations to these farmers. A comparison of thinning versus no thinning can be superimposed on tillage, planting and fertilizer trials. Tillage and planting systems' trials with fertilizer comparisons, conducted by ATIP, have not involved thinning, but a thinning comparison would have been useful to ascertain the cost of not thinning.

(d). Research, particularly by the FSR teams, should involve extension staff, in addressing the problems of planter maintenance and sheltering. ATIP designed and helped administer a Planter Condition Survey [ATIP RD 89-2, pp. 51; ATIP WP 38]. Several problem areas have been identified that need follow-up (see Section 4.4.3.1).

(e). With the results obtained during ATIP research, a recommendation that resource poor farmers in the ATIP areas purchase fertilizer to use in their farming systems, should not be made unless the reliability of plant establishment and water conservation is greatly improved.

(f). For resource poor farmers, research should focus more attention on the use of soil building options instead of on the use of chemical fertilizers.

4.4 PLANTING METHODS AND POST-ESTABLISHMENT PRACTICES

4.4.1 ROW PLANTING VERSUS BROADCASTING

4.4.1.1 Justification

This section gives an overview of the issue of row planting versus broadcasting based on a large volume of research undertaken in Mahalapye and Francistown. Row planting has for a long time been a major recommendation of the Ministry of Agriculture in Botswana, even though the rate of adoption in the Central Agricultural Region and the Tutume Agricultural District is very low [Singh, Kelly, and Motsemme, 1981, p. 106]. Lightfoot [1981] suggested that broadcast planting is appropriate for most small farmers in Botswana. This is because broadcast seeding followed by one plowing allows farmers to respond to the rainfall pattern that unfolds in any given season. The single plow/broadcast system permits farmers to plow-broadcast whenever rain falls and to plow/broadcast as much as rainfall permits without making a large investment on any portion of land. In its final report, however, EFSAIP indicated that results from the conventional broadcast and row planting comparison were variable and circumstantial, but that there was a positive profit over a four year period in shifting from broadcast to the use of row planters [EFSAIP, 1984, p. 174].

ATIP has conducted several trials focused on screening technological options. The comparison of row planting systems with broadcast systems has often been part of these trials. There have also been three RMFI trials to compare the management requirements of row planting and broadcast, and to evaluate particular implementation strategies (see Table 4.12). In total, plot comparisons of row planting and broadcast seeding have been reported for 53 different farm-seasons. In many of these comparisons, more than one type of row planting or broadcast system was included, and with usually more than a single replication per farm. A list of ATIP trials in which row planting and broadcasting were compared is given in Table 4.12.

TABLE 4.12: ATIP ACTIVITIES RELATING TO PLANTING METHODS AND POST-ESTABLISHMENT PRACTICES

MAJOR FOCUS	MORE DETAILS	YEAR[a]	AREA	SAMPLE[b]	TYPE[c]	TRIAL	ATIP PAPERS		
Comparison broadcast versus row plant	Planting methods	1982	Mahal.	4	Trial	RMFI	RD 83-1, p.V.27-29	DAR 84, p.176-179	
	Effectiveness of sole plowing	1983	Mahal.	9	Trial	RMFI	RD 83-1, p.V.29-31	RP 1 p.174-193	
	Steps in technology	1983-4	F'Town	2,3	Trial	RMRI	RD 84-1, p.8.22-8.25	RD 85-1, p.8.27-8.40	WP 5, p.8-12
	Maximum production	1983-4	F'Town	1,3	Trial	RMFI	RD 84-1, p.8.20-8.23	RD 85-1, p.8.5-8.11	WP 5, p.3-8
	Tillage/planting scheme	1984	Mahal.	9	Trial	RMFI	RP 1, p.174-193		
	Commercial steps in technology	1984-6	Mahal.	4,5,5	Trial	RMRI	RD 85-1, p.7.26-7.30	RD 86-1, p.54-57	
							RD 87-1, p.II.37-39	EP 89-4	
	Tillage systems	1985-6	F'Town	2,2	Trial	RMRI	RD 86-1, p.96-98	RD 87-1, p.II.68-70	PR F86-5
							PR F87-5		
	Water conservation systems	1985-6	Mahal.	3,3	Trial	RMRI	RD 86-1, p.57-59	RD 87-1, p.II.35-38	
							DAR 1987, p.100-101		
Plant population control	Thinning	1985	Mahal.	8	Trial	RMFI	RD 86-1, p.64-5		
		1986	Mahal.	19	Trial	RMRI	DAR 1987, p.89-91		
	Replanting failed plots	1986	Mahal.	38	Study	---	RD 86-1, p.67-8		
	Gap-filling and hand replanting	1985	F'Town	3	Trial	RMFI	RD 86-1, p.100-2	PR F86-4	
		1986-7	Mahal.	13,9	Trial	RMRI	RD 86-1, p.65-6	RD 87-1 p.II.39-42	
	Relay planting	1984,7	Mahal.	9,17	Trial	RMFI	RP 1, p.206-1	RD 88-1, p.37-8	
Planting methods	Animal drawn planters	1989	Both	157	Survey	---	RD 89-2, p.51	WP 35	
	Hand row planter:	1986-7	F'Town	20,10	Trial	FMFI	RD 87-1, p.II.74-75	RD 88-2,p.63-68	PR F88-4
								RD 89-2, p.79-89	
							PR F90-2	PR F90-6	
	Economics	1987	Mahal.	14	Trial	FMFI	RD 88-2, p.45-46		
	Test of improved local model	1988	Mahal.	5	Trial	FMFI	RD 89-2, p.56-58		
	Survey of those using new model	1988	Both	39	Survey	---	RD 88-2, p.59	PR F88-4	
	Level of adoption	1989	F'Town	158	Survey	---	WP 34		
	Impact of fertilizer and tillage	1989	Mahal.	---	Paper	---	EP 89-5		
	Custom-hire row planting	1987	Mahal.	20	Trial	FMFI	RD 88-2, p.38-39	PR M89-1	
Weeding	Farmer practices	1985	F'Town	213	Survey	---	RD 85-1, p.8.11-8.18	WP 3	
	Magnitude of Constraint	1983-4	F'Town	6	Trial	RMFI	WP 5, p.10		
	Weeding Rates	1990	Gaborone	---	Study	---	PR G90-2, p.4		

a. The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season, and 1984-5 refers to both the 1984-85 and 1985-86 cropping seasons.

b. Refers to the number of sites or farmers. RMRI trials will usually have more than one replication at each site. Figures in the column separated by a comma indicate sample sizes in different years.

c. This can refer to a study, survey, trial or paper.

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Date. September 5, 1990

The objectives of the comparison between row planting and broadcast were to:

(a). Determine which type of planting or tillage and planting system was most appropriate for small farmers.
(b). Determine which system had the highest production potential in this environment.

4.4.1.2 Results And Conclusions

In ATIP, broadcast and row planting came to be viewed and evaluated as part of the tillage and planting method systems. The tillage and planting method systems that were included in the work are listed below. For the row planting work, only trials with comparisons using animal or tractor drawn units, are listed. The work with hand operated planters has not been included because it dealt more with the evaluation of the equipment than the system.

Under broadcast, the following systems have been tested:

(a). Broadcast and single plowing.
(b). Early plowing plus broadcast and second plowing (double plowing).
(c). Early plowing plus broadcast and harrowing.
(d). Early plowing plus broadcast and cultivating.

Under row planting, the following systems were tested:

(a). Conventional plowing and row planting.
(b). Early plowing and row planting.
(c). Double plowing and row planting.
(d). Early plowing plus cultivation and row planting.
(e). Early plowing plus harrowing and row planting.

An important question when comparing row planting and broadcast seeding is which planting method best facilitates tillage and water conservation recommendations. These issues are considered in the following discussion. A brief summary of the results and conclusions derived from these studies and trials, are as follows:

(a). Row planting sometimes gave a better percent field emergence for sorghum than broadcast seeding under conventional (i.e., single plowing) and double plowing [DAR, 1988, pp. 92-94; ATIP WP 5, p. 6, 10; ATIP RP 1, p. 179]. The variability for plant emergence from row planting was high, and the average was well below the 60 percent plus that was desired. The consistency of emergence improved somewhat with early plowing, regardless of the planting method. As would be expected, the best emergence from row planting occurred under conditions that favored emergence under single plow/broadcasting. This underscored the importance of rapid plowing and planting under conditions conducive for good emergence [DAR, 1988, pp. 92-94]. It is important to note that the return to seed will likely be of greater importance for high value crops, such as cowpea and groundnut. It has therefore not been surprising to see a strong interest among ATIP research farmers in row planting these crops.

(b). Agronomically, the difference between row planting options and broadcast seeding options was not very clear when the plot data were examined. Generally, row planting resulted in a higher grain yield than single plow/broadcasting [ATIP WP

5; ATIP RP 1, pp. 179-180; DAR, 1987, pp. 109-113; ATIP EP 89-4; ATIP MP 88-6]. In these same trials there was generally no significant differences between row planting systems, and double plowing with broadcast seeding. In a stability analysis, there was some evidence that row planting gave better plot yields than double plowing under higher yielding environments [ATIP EP 89-4], and double plowing plus broadcasting appeared to perform better under poorer yielding environments.

An analysis of yield components for sorghum resulted in nearly the same average tillering number per plant and head weight. Differences in grain yields appeared to be mostly related to differences in plant stand [DAR, 1987, pp. 119-123; ATIP RP 1, p. 179). However, at typical seeding rates for broadcast planting, conventional and double plowing sometimes gave excessively large populations which reduced their yield potential in many seasons. In some ATIP trials, broadcast seeding rates were reduced in order to lessen this problem particularly under double plowing [ATIP WP 5, p. 4, 10].

It was noted that following stand establishment, the only agronomic advantage for row planting over broadcast seeding would be through the better distribution of plants. An ideal distribution is likely to give a higher yield per plant for the same population. This benefit is likely to be modest in extensive systems like the one practiced in Botswana, and is certainly over shadowed by other factors in the ATIP data sets.

(c). A detailed economic analysis of double plowing and early plowing plus row planting was undertaken [ATIP RP 1, pp. 182-193]. All of the budget comparisons were between single plow/broadcasting and early plowing plus row planting, or between single plow/broadcasting and double plowing. In this analysis, both the broadcast double plowing and early plowing plus row planting systems provided net gains of P27.00 per hectare above the single plow/broadcasting system. Several important points relating to this analysis are:

i. Yield data were from row planting that was done by individuals not very experienced with the operation.

ii. No opportunity cost was given to performing early plowing before row planting instead of plowing on the day of planting. In both cases, just one plowing operation was involved. However, there may be additional costs due to heavier weed burdens when early plowing.

iii. No benefit in the analysis was given to labor saving possibilities as a result of mechanical weeding following row planting. Mechanical weeding was not done.

For many households, there was a lack of row planters and other resources for undertaking the planting operation. In addition to the ALDEP subsidy on the purchase of planters, this resource constraint has been dealt with under several research topics including the rotary injection planter (Section 4.4.3.2) and the custom-hire row planting scheme (Section 4.4.3.3).

There are a number of points to be made when extrapolating experimental results on row planting to that of production under practical farming conditions. These are as follows:

(a). Separation of tillage and planting gives greater flexibility when selecting tillage options. Tillage options include: early spring plowing, early plowing with

secondary tillage, deep plowing, winter plowing, and plowing with planting on the same rain. Except for the speed of the planting operation compared with the second plowing, these options pertain to double plowing as well as row planting.

(b). Early plowing and later row planting can generate weed problems at, or soon after, planting [ATIP PR F87-8; ATIP MP 87-7; ATIP MP 87-9]. Increased weed problems were observed in about 50 percent of the trial implementations [ATIP MP 87-9]. When this occurs in the early plowing and row planting system, cultivating [ATIP MP 87-9, p. 4] or double plowing [ATIP PR F87-8; ATIP PR F86-5] may be required before planting. Cultivating immediately before planting was found to significantly improve weed control [ATIP MP 87-9, p.4].

(c). The most important benefit of row planting is its potential to plant larger portions of fields in a day, compared to the broadcast/plow system. This can allow more planting to be done on days with good soil moisture. This good soil moisture window can be very narrow in some seasons [ATIP RP 1, pp. 141-143]. Even though the speed of row planting depends on a number of factors -- such as, type of planter and preparation of equipment, animal teams, labor, soil conditions, etc. -- several mean values have been reported that permit a comparison of plowing and planting operations.

The best estimate of row planting operation time for a single row animal drawn (i.e., donkeys) planter, is around 4.5 to 5 hours per hectare [ATIP PR M89-1]. This time is for experienced operators working on one hectare plots. The time also compares favorably with the time reported by EFSAIP [1984, p. 301]. Longer times are also reported elsewhere [ATIP PR G90-2; ATIP PR M89-1], but these appear to reflect the problem of inexperience with row planting. These values compare with an estimate of more than 24 hours per hectare for donkeys doing a second plowing in a double plowing system, and 16 hours for cattle [ATIP PR G90-2].

(d). Row planting creates the potential for mechanical weeding thereby increasing the return to weeding labor. Mechanical weeding could also improve soil aeration and water infiltration during the period of crop growth. Some estimates that have been obtained for hand hoe weeding of sorghum have been 20 to 40 person-hours per hectare in broadcast plots [ATIP MP 87-7; ATIP MP 87-9]. Mechanical weeding is reported to take eight hours per hectare [ATIP PR G90-2; EFSAIP, 1984, p. 301].[20] The shift from hand hoe weeding to mechanical weeding can result in a labor savings. However, it will require a shift to the use of more labor for mechanical operations, which are usually done by men, in contrast to hand weeding which is generally the preserve of women.

(e). Lack of experience and skill, and intensive crop management with reference to row planting were serious obstacles in the adoption and correct implementation of this operation [ATIP WP 5; ATIP PR M89-1; ATIP WP 29; ATIP MP 88-18]. The broadcast system, including double plowing, is much easier for farmers not trained in how to row plant.

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[20]. That is for inter-row cultivation. Intra-row cultivation, which needs to be done by hand, would be extra. Also since two people are needed for mechanical weeding, the actual operational time is four hours per hectare.

4.4.1.3 Recommendations

Over the years, a series of decisions have been made in ATIP with regard to row planting versus broadcast seeding.

In the first years of ATIP, more attention was given to broadcast systems than row planting. ATIP still finds double plowing useful and supports recommending this system for many households and circumstances. Thus, there has been considerable focus on double plowing work in the farmer implemented format, as the first step up the technology ladder.

In recent years, there has been an increase in the amount of work carried out on row planting, although at the moment, row planting cannot be successfully implemented by most farmers in the ATIP areas. Therefore ATIP activities have focused on identifying ways of making row planting practical for more households under farmer managed conditions. As a result, the following recommendations were developed and are in the process of being implemented:

(a). The constraints for standard row planting -- lack of traction, equipment and labor -- have been and should continue to be addressed through two research activities, namely:

i. Testing of the hand operated rotary injection planter. This planter is the last and most successful of three hand operated planters that have been tested (see Section 4.4.3.2)

ii. Organize training, equipment and scheduling for custom-hire row planting that is to benefit households that cannot do their own row planting (see Section 4.4.3.3).

(b). Some ATIP investigations have focussed on extension forums that support row planting. These were designed to help alleviate the constraints of inexperience and lack of skill and knowledge. Avenues explored, in collaboration with other agencies in MOA, have been and should continue to be:

i. The promotion of a row planting package through contests at District Agricultural Shows (see Section 3.5).

ii. The development and implementation of farmer training courses on the use of planters and a row planting system (see Section 3.3).

(c). Row planting and mechanical weeding equipment options should continue to be included in the Extension-Oriented Farmer Groups, and advice on how to use them correctly must be given.

(d). Part of the ATIP's workplan should continue to include research on problems that are identified in the promotion of row planting.

A **Promising Guideline** on row planting and inter-row mechanical weeding has been prepared (ATIP Ex' 6, Section 2.2.4)

4.4.2 POPULATION CONTROL: THINNING AND GAP-FILLING

4.4.2.1 Justification

Thinning and gap-filling are practices that can be used to correct inappropriate plant populations following assessment of the initial planting. Under typical farmer management in the ATIP research areas, the variation in plant stands achieved was high. Even a practical target of 20 to 60,000 sorghum plants per hectare was not easily obtained by farmers (see Section 4.3.1).

ATIP began investigating thinning and gap-filling in the early part of the project as a response to the problem of plant establishment. This work continued until the sixth season of the project when it was felt that enough information had been collected. With time, ATIP researchers began to recognize the need to specify the type of thinning or gap-filling, and the circumstances under which the practices were being investigated. Under thinning, three circumstances requiring different approaches were identified:

(a). Excessive broadcast populations such as stands that far exceeded 100,000 sorghum plants per hectare.
(b). Broadcast stands with more acceptable plant numbers but with crowding occurring in some places.
(c). The cropping strategy of deliberately overseeding and thinning back to precise plant stands. This generally pertained to row planted stands.

Under gap-filling practices, three or four circumstances were noted:

(a). Re-planting a completely failed plot.[21]
(b). Gap-filling large areas within a plot.
(c). Gap-filling as in (b), but for smaller gaps within a plot.
(d). Relay planting. Following the establishment of one crop, a second crop is seeded in the gaps. Relay planting can be either pre-planned for specific enterprises or practiced on an opportunistic basis.

The main objectives related to thinning and gap-filling of the several ATIP trials and studies that included these practices were as follows:

(a). To identify circumstances in the farmer's operations where thinning or gap-filling could be used.
(b). To evaluate the return to these practices. Most often, the return was expressed in harvest benefit per labor unit used.
(c). For gap-filling, and for thinning excessive plant stands, to evaluate appropriate methods that could be used by farmers.
(d). To identify crops of choice for gap-filling strategies.
(e). To obtain farmer assessment of these practices.

One can note that the work on methods appropriate for gap-filling (objective (c)) evolved into the testing of hand planting options for farmers with poor access to traction and standard planting equipment. Hand planting options are discussed under Section 4.4.3.2.

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[21]. In the references, plot as used here, is sometimes referred to as an "acre" by farmers. An "acre" represents a block of land that is typically plowed and planted as a unit.

4.4.2.2 ***Results And Conclusions.*** Briefly, the results and conclusions are as follows:

(a). ***Thinning Excessive Stands.*** When farmers thinned sorghum stands that they had identified as over populated [ATIP RD 86-1, pp. 64-65], thinning was clearly not economical. This can be explained because thinning was followed by drought stress during which many plants, even with thinning, didn't survive. Differences between thinned and unthinned stands were noted mostly on the basis of plant vigor and plant survival, with little yield achieved on any plots. In order to be profitable, thinning had to be on stands that were viable, with sufficient soil moisture reserves available. Farmers who participated in thinning work indicated some interest in the results, but most were reluctant to thin early enough or intensely enough to meet the guidelines of thinning to 50,000 plants per hectare at the earliest stage possible. ATIP researchers concluded that most farmers would be reluctant to perform a special thinning operation before the normal weeding time.

(b). ***Thinning Crowded But Viable Plant Stands.*** Sub-plots within a farmer implemented double plowing trial were thinned -- target of five to six plants per square meter -- by researchers. The original purpose of this thinning was to investigate whether the effect of the plowing treatment went beyond plant establishment [DAR 1987, pp. 89-91]. Because most plant stands in this trial were comparatively good before thinning, the superimposed thinning was used to evaluate the need for close attention to plant density. In this instance, thinning consisted simply of removing the smallest plants from occasional pockets of heavy stand. A few farmers indicated that they already thinned pockets in this way. In the trial, the slight reduction in plant stands due to thinning was not significant. However, a small increase in grain yield was significant. Such a small benefit was not likely to be economically advisable except when thinning was combined with weeding.

(c). ***Overseeding And Thinning Plant Stands.*** Towards the beginning of ATIP work, a strategy of overseeding and thinning back was discussed as an option for farmers to more reliably achieve appropriate plant stands. This option was recommended tested by EFSAIP [EFSAIP, 1978, pp. 4-6].[22] This strategy was not directly tested with ATIP farmers, because of the already poor response shown by farmers to thin heavy stands that had not been planned. ATIP research has only worked with overseeding as part of the National Tillage Trial. In this trial, row planted stands were overseeded but thinning could be handled systematically. In general, ATIP research has tended to use seeding rates that were likely to give desired plant stands and to look for ways to improve planting moisture -- that is, early tillage to provide a wet seedbed.

(d). ***Re-planting Completely Failed Plots.*** Near the beginning of the project, ATIP researchers found a few farmers who occasionally broadcast seed and then plowed again or harrowed when the first plow/planting had failed. In terms of outcome, this practice corresponded closely to double plowing that was already part of the trials' work. A small investigation was made into why such re-planting wasn't practiced by more farmers [ATIP RD 86-1, pp. 67-68]. Generally the issue for the farmer was whether to re-plant failed plots or to continue plow/planting on untilled land.

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22. This had previously been recommended by an earlier project, the Dryland Farming Research Scheme (DLFRS).

Two results of the study were of interest. These were as follows:

i. The pattern of rainfall often limited the number of times in a season that a decision on whether to re-plant or continue new planting, needed to be made. If plow/planting began late, there was not always an opportunity for re-planting.

ii. A substantial delayed emergence occurred following many plantings. With the delayed emergence, it became difficult to decide immediately whether re-planting should be done. In the 1985-86 season, an average of 20,000 sorghum plants per hectare emerged following rains more than six weeks after planting. Clearly, these results were circumstantial, but indicated that farmers who broadcast should wait at least one post-planting rain before deciding to re-plant plots that appear to have failed. Delayed emergence on row planted plots was less likely to occur than with broadcast plots, particularly if they were planted into good soil moisture.

(e). *Gap-Filling Large And Small Gaps Within Plots.* Gap-filling received a considerable amount of attention during the middle years of ATIP research. As with plot re-planting, gap-filling did not always fit into the system; particularly when planting was late in the season [ATIP RD 85-1, p. 7.39]. Another problem encountered with testing gap-filling was that some trials involved plots arranged before planting. Because gap-filling relates to the circumstance of poor plant establishment, gap-filling was often not appropriate [ATIP RD 86-1, pp. 100-102; PR F86-4].

Results for gap-filling were generally favorable when the practice was targeted to areas where plants had not been established. In these trials, the issues of planting moisture and crop or variety to use were investigated. Hand planting sorghum and millet gave satisfactory stands [ATIP RD 86-1, pp. 65-66]. Millet performed better than sorghum when hand planted on dry soil. Grain yield and return to labor for hand planting of sorghum, millet, ER-7 cowpea, black-eye cowpea and maize were compared. Only maize failed to produce sufficient yield to show a profitable return to the labor for hand planting [ATIP RD 87-1, pp. II.39-II.42]. Hand jab planting of four cowpea varieties was also successful [ATIP RD 85-1, p. 7.39-7.40].

Increasingly, it became clear that the attractiveness of gap-filling and hand planting generally depended on the equipment available to perform the task. Farmers were familiar with gap-filling by broadcasting seed and covering with a hand tool, or hill planting with a hoe or a planting stick. Gap-filling with these instruments was not widely practiced. Details on hand planters that have been tried, are as follows:

i. The first planter used by ATIP was a hand jab planter. This unit was modeled after hand jab maize planters available in the USA. These units were manufactured locally in 1983 for P22.00 each. They were most suitable for large seeded crops. The planter was slightly too heavy and planting was slow. Even with experience, most farmers did not find planting with this unit to be attractive. Because seed was placed in the unit by hand, small seeded crops were difficult to disperse at the desired rate.

ii. The Sanitas push planter was mostly used to plant vegetable plots. This unit was imported from Sweden by Sanitas of Gaborone. Planting time was

estimated at 10 hours per hectare on small plots with good tilth. It was difficult to maintain this rate over a large area. There were some difficulties with seed flow and covering of seed when soils were slightly dry. The unit was very portable and was found to be most useful for planting small gaps dispersed around the field.

iii. The move to the rotary injection planter (see Section 4.4.3.2) led away from gap-filling to research on a system of hand planting plowed land that had not been planted.

At the request of several farmers, transplanting of thinned sorghum plants was used to fill gaps in the field [ATIP RD 86-1, pp. 65-66]. Survival rates were reasonably good and plants produced some grain. However, labor time for transplanting was ten times that for using the Sanitas or rotary injection planter. From these results, it was suggested that transplanting might possibly be useful for very late planting where a new seedling could not reach maturity. After a single season, though, ATIP researchers decided not to work further on transplanting.

(f). ***Relay Planting.*** Relay planting consisted of planting one crop with the intention of inter-planting a second crop after the first was well established or even near maturity. The second crop exploited space, nutrients and soil moisture not utilized by the first. In two relay planting trials, short cycle crops[23] or varieties that could be planted late were inter-planted [ATIP RP 1, pp. 200-201; ATIP RD 85-1, pp. 7.33-7.34; ATIP RD 88-1, pp. 37-38].

Relay planting was not profitable in either trial. In the earlier trial, planting of the first crop was generally late and few opportunities for second planting occurred. This situation can occur frequently for households with poor access to traction. In the second trial, stands of groundnut which were planted first were satisfactory, and there was little need for relay planting.

4.4.2.3 Recommendations

As a result of the work done on thinning and gap-filling, it is recommended that:

(a). Farmers should place low priority on the thinning of large plots that have excessive plant stands under broadcast. These farmers could make better use of labor, weeding plots with more satisfactory stands. Thinning should be commenced when the more satisfactory stands have been attended.

(b). Pockets in broadcast plots, with excessively high plant stands, should be thinned as part of the hand hoe weeding operation.

(c). Farmers should adopt an opportunistic approach to plot re-planting. If it is certain that significant emergence of seed is completed and a planting rain falls, a farmer should broadcast and re-plow -- or cultivate -- any failed area. This procedure corresponds to double plowing (Section 4.2.1.2). If additional emergence is still possible, the farmer should plow/plant untilled land, if available.

(d). Farmers should also adopt an opportunistic approach to gap-filling. If equipment,

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23. For example, mung beans, cowpeas, sunflower and maize.

seed, and labor are available; farmers can profitably gap-fill at a rainfall opportunity during the planting season. The best choices for gap-filling are large seeded, high value crops.

(e). Relay planting should be not be treated as a pre-planned activity, but as an opportunistic option for appropriate circumstances. In this situation, relay planting becomes similar to gap-filling.

4.4.3 ROW PLANTING

4.4.3.1 Animal Drawn Row Planters

(a). ***Justification.*** Row planters have been available in Botswana for many years. In spite of this, relatively few farmers row plant and even fewer produce technically good results. In addition to a lack of knowledge and managerial skills with respect to row planting, poor results may also be because of the poor condition of many of the row planters owned by farmers.[24] Therefore, in collaboration with extension and FMDU staff, a survey of 157 farmers owning row planters in a total of 17 villages was undertaken in 1989 in the Francistown, Mahalapye and Southern areas to ascertain the characteristics of farming families who owned row planters, the amount of row planting they did, their knowledge and opinions about row planting, and an assessment of the condition of the row planters themselves.

(b). ***Results And Conclusions.*** The results can be summarized as follows:

i. ***Household Characteristics.*** The average age of the household head was about 58 years old, with an average size of household of about seven. However, the households owning row planters were obviously not representative of all the households in the surveyed areas. For example, 83 percent of the households were male-headed, and they tended to represent the wealthier farmers since only nine percent did not own cattle.

ii. ***Equipment.*** The average age of the row planters surveyed was seven years old. Seventy-four percent of the planters consisted of three makes: Safim (46 percent), Sebele Row Planter (15 percent) and the Sebele Plow Planter (13 percent). Not surprisingly, because of the importance of properly controlling the animals, only 28 percent of the planters were pulled by oxen, and the remainder by donkeys. Generally row planting was done with a team of two people, usually consisting of at least one man assisted by a child.

iii. ***The Practice Of Row Planting.*** Seventy-six percent of the row planters were used every year, but when the surveyed farmers last row planted, 39 percent did not row plant all of the land they planted. On average, for the sample as a whole, 16.7 hectares were planted of which 14.0 hectares were row planted. The major reason given for both not using the row planter every year, and for

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[24]. This notion was prompted, in part, by the observations that many of the planters used in the trials were in poor condition, and by the results of a Plow Condition Survey conducted a few years earlier. This survey found that many of the plows were very old, had missing parts, and were badly adjusted. Because of this they required more draft power to operate than would normally be necessary and did a technically poorer job [ATIP PR F84-4].

not row planting all the land planted, was a shortage of labor. In terms of land preparation prior to row planting, 56 percent did just one plowing, 26 percent double plowing, and 18 percent one plowing plus harrowing. Somewhat surprisingly perhaps, although probably because they tended to be wealthier farmers, 26 percent of the farmers used manure and 62 percent applied fertilizer. However, this apparent progressive feature was not reflected in the weeding operation. Sixty-three percent of the surveyed farmers only weeded by hand, while those who weeded mechanically were surprisingly equally divided between oxen and donkeys. Thus, for many farmers, one of the major advantages of row planting -- that of saving labor for weeding -- was not exploited. When mechanical weeding was undertaken, the Mahon cultivator was generally used. Only 24 percent of the farmers kept their row planters in the open.

iv. *Farmers Perceptions.* When asked to state and rank the advantages of row planting, the most common was that it saved weeding labor, followed by the fact that it promoted good plant stands and early plant vigor, that the crops were easier to harvest, and that the air circulated amongst the plants. In terms of problems experienced with row planting, a significant minority -- 20 to 45 percent -- had problems that could be classified as logistical, planting, mechanical, and/or handling in nature. What was of particular concern was that almost 80 percent had received no help in dealing with the problems encountered. With reference to repairing planters, over 90 percent with problems had received no help and 80 percent indicated spare parts were not available. In spite of this, 82 percent of the farmers indicated their planters were currently in good working condition.

v. *External Evaluation.* To provide an independent check of farmers' knowledge concerning row planting and an evaluation of the row planters themselves, a staff member from FMDU visited 73 percent of the households. He concluded that the farmers' overall knowledge of row planting was average. With respect to different aspects, he found farmers' knowledge about planter adjustment, optimal conditions for row planting and width of row planting were good, while knowledge of routine maintenance was only average. Overall inspection of the row planters revealed that most of them were in reasonable working condition, confirming the farmers' perceptions. Therefore for the sample of farmers surveyed, the results appeared to be reasonably satisfactory. However, care must be taken in coming to this conclusion. Reasons for this are as follows:

-- There was no sampling frame of farmers owning row planters to select from. The sample was selected by contacting ADs and knowledgeable people in each of the sample villages as to who owned row planters. Thus the sample was likely to be biased towards farmers who were then row planting, and against those farmers who for one reason or another had given up row planting.

-- Assessment of farmers' knowledge was based on a question and answer format rather than practical assessment in the field.

(c). *Recommendations.* As well as a **Promising Guideline** on row planting [ATIP RP 6, Section 2.2.1] it is recommended that:

i. Efforts are made to ensure that farmers can get help in handling problems

through improving ADs' practical expertise in dealing with problems relating to row planting.

ii. It is necessary to improve the local availability of spare parts at commercial outlets in the area, for all equipment being distributed to farmers through government programs.

iii. It is desirable to continue the recently adopted initiative of ALDEP to provide row planters and inter-row cultivators as an integrated package.

iv. It is desirable to offer practical "hands on" training to farmers on row planting and inter-row cultivation, and also on routine maintenance and adjustment of the equipment, through farmer groups, farmer training courses, etc.

4.4.3.2 Hand Row Planters

(a). ***Justification.*** Part of the responsibilities of FSR involves presenting new technologies to farmers, to determine whether the farmers have any interest in them, and to test the effectiveness of those technologies should such interest exist. It was on this basis that two types of hand row planters (HRPs) were introduced to farmers by ATIP staff. Work on the hand row planters was justified on the following grounds:

i. It was believed that hand row planters were potentially important for farmers who did not have ready access to draft. It would open up the possibility of doing the planting in a timely manner when plowing was done at a non-optimal time for planting -- that is, when soil moisture was not adequate. Farmers in the ROFG in Mathangwane indicated in group discussions that this commonly occurred when draft power was obtained through hiring or borrowing, because farmers then had to use the draft power when it was available, rather than using it when planting conditions were optimal.

ii. Good row planting could be difficult to achieve when using oxen, particularly for women on their own. It was believed that hand row planters might be attractive for farming households where:

- There was no access to donkeys, and/or
- Women were responsible for the planting, and/or
- Only small areas of land were to be row planted

Two types of hand row planters were tested, the "Sanitas" HRP and the Rotary Injection Planter (RIP).[25] Activities relating to them are listed in Table 4.12.

(b). ***Results And Conclusions.*** Results with reference to each type of planter are as follows:

i. ***The Sanitas Hand Row Planter.*** The name for this HRP derives from the fact that it was first observed by ATIP staff in use by the Sanitas company in

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[25]. In some of the ATIP papers this has also been called the Masdar or Master Planter.

Gaborone. This HRP consisted of a long, tubular handle with two disk furrow-openers on one end, a seed brush-agitator between the disks, and a simple seed-metering device, also between the two disks. ATIP staff added a drag chain behind the furrow-openers to cover the seed.

This HRP was only tested informally by farmers (FMFI trials) and the work has not been officially reported in publications. Personal observations and discussions with farmers who used this HRP resulted in the following conclusions:

-- The Sanitas HRP was not useful for planting large areas in fields because the small circumference of the furrow-openers made the machine too difficult to push over plowed (uneven) ground.

-- The machine did a reasonable job of planting when used. It was quite appropriate for filling gaps where initial seedling emergence was poor. This was because the machine was light weight and easy to carry around the fields, and because it allowed re-planting to be done without the use of animals, the need for re-plowing, or the need to dig holes with a hoe.

This HRP was introduced to farmers in 1986, and although it has not been promoted by ATIP in recent years, there are still farmers who come to the ATIP compounds in the villages and request to borrow the machine for gap-filling.

ii. ***The Rotary Injection Planter (RIP).*** This HRP was originally developed at the International Institute for Tropical Agriculture (IITA) in Nigeria. It was first introduced to Botswana by the ANDP project in Ngamiland. The RIP consisted of a seed hopper attached to the center of a six-sided wheel. At each corner of the wheel were "injectors" that opened a hole in the soil when the wheel was turned. Seeds fell from a metering device at the base of the seed hopper into these holes. The device could be pulled or pushed by a long handle which was attached to the central axle of the wheel.

ATIP began to work with the RIP in 1986. Most of the trials were conducted in an FMFI format. The results of testing done between 1986 and 1989 are reported in a number of places (Table 4.12). The RIP could be operated by one person compared with a minimum of two required for a row planter with donkeys. The limited amount of data collected indicated that the time to row plant a hectare with a RIP was about 15 hours compared with about 8 hours using donkeys [ATIP PR G90-2, p. 4].[26] Thus they were equal in terms of the number of person-hours of labor required to plant a hectare, although a donkey team could cover the area much faster.

The major conclusions arising out of the work on the RIP were as follows:

-- The first locally produced RIPs underwent several modifications based on both farmer and researcher suggestions for improvement. At present a prototype exists which is quite good, but is still in need of minor modifications to the seed metering device before going on sale

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26. This excludes time involved in collecting the animals and hitching them up.

to farmers.

-- The RIP is potentially useful to farmers and has confirmed **ex ante** reasons for testing it, namely:

. It allows farmers without draft power to separate the plowing and planting operations. This allows them to better control the day of planting instead of being forced to plant on whatever day they can obtain draft power.

. It is easier to make straight rows when pulling a machine by hand[27] than when cattle or donkeys are used.

. Using the RIP does not free farmers from the responsibility of using good judgement in selecting a planting date and doing the planting in a timely manner.

. A survey of farmer participants in the ROFGs, conducted in the Francistown area in 1989, showed that the RIP was the second most commonly adopted technology, after double plowing. "Adopted technologies" were defined as technologies that farmers used on their own fields outside of ATIP trials. This is a strong indication that at least some farmers considered the RIP to be a useful tool.

(c). ***Recommendations.*** Recommendations concerning the hand row planters, are confined to the RIP on which a **Promising Guideline** has been produced [ATIP RP 6, Section 2.2.2]. They are as follows:

i. A reasonably functional RIP can be, and has been, produced in Botswana. However, the most recent model still requires some minor modifications to the brush, which at present tends to jam the flow of grain from the seed hopper to the seed wheel in large seeded crops. Other useful modifications have been recommended by FMDU, and the MDP, both in DAR, to ALDEP. The recommended modifications should be effected, and the modified machine should undergo minor field testing to verify that the modifications have solved the problem.

ii. These machines should then be demonstrated widely in different regions to determine demand, and initial trial sales through ALDEP should be initiated in regions where demand seems to exist.

iii. ALDEP and DAR personnel should continue with developing and testing further modifications of the machine, to make it easier to dismantle -- to change the seed wheel -- and to test a two row model that could be pulled by a donkey.

4.4.3.3 Custom-Hire Row Planting Scheme

(a). ***Justification.*** Many farmers in the Central Agricultural Region have indicated an

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27. Pulling was found to be more satisfactory than pushing.

interest in row planting. However, the primary constraints to row planting have continued to be little knowledge on how to row plant combined with limited access to the necessary inputs, including draft, row planting equipment and labor [ATIP RP 1, p. 71]. While custom-hire arrangements have traditionally been used by Batswana farmers in order to gain access to scarce plowing resources, such arrangements for row planting have rarely been made [EFSAIP, 1983, p. 82].

A survey conducted in Makwate and Shoshong villages indicated that 60 percent of the surveyed farmers believed that row planting could increase production [ATIP RP 1, p. 70]. Also, interest in row planting seemed very high with very few mentioning that the extra expense associated with row planting was prohibitive [ATIP WP 17]. Therefore, an apparent gap has developed between what farmers believe is beneficial for production, and their abilities to acquire the resources and skills necessary to implement improved practices.

Given the level of interest in row planting, and the potential time saving in weeding by combining it with mechanical weeding, ATIP decided to test a custom-hire row planting scheme during the 1987-88 season in Makwate and Makoro villages. ATIP references where details are discussed are listed in Table 4.12. The objectives of the scheme were to:

i. Increase the areas row planted while at the same time demonstrating good quality row planting.

ii. Link row planting with mechanical weeding.

iii. Test whether or not a custom-hire approach was a viable option, thereby creating employment opportunities for young men in the villages by row planting for other farmers, under the ARAP scheme.

Once row planting was adopted, a foundation would be created for further recommended inputs such as band application and a top dressing of fertilizer which were not feasible under the traditional broadcast system.

(b). ***Results and Conclusions.***[28] Because young under-employed men were generally either unavailable or unreliable, farmers, who were currently active, were offered the opportunity to be trained to do custom-hire row planting. Extension and ATIP personnel were involved in the selection process, while a number of criteria were used in identifying potentially suitable individuals. Those considered eligible were those who demonstrated an interest, had access to labor and draft, and were able to maintain their own arable operation during the planting/weeding period. An intensive one week "hands-on" training course was then undertaken in Ma'ialapye during September 1987, involving nine selected custom-hire operators.[29] The selected operators were also given assistance in obtaining equipment, and in arranging contracts with farmers who wished to have one hectare plots row planted. ADs in the two villages assisted with the contractual arrangements. ARAP subsidies were used to pay the custom-hire operators.

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[28]. More details on the approach used, and the results derived from the custom-hire scheme are presented elsewhere [ATIP PR M89-1].

[29]. Only three eventually did some custom-hire row planting.

The scheme was first publicized at an October **kgotla** meetings, jointly organized by district extension and ATIP personnel. Eventually, a total of 20 farmers[30] -- 12 in Makwate and eight in Makoro -- had their land row planted under the scheme. Farmers participating in the scheme were required to plow and leave one hectare unplanted which would then be row planted by the custom-hire operators.

Briefly some of the major results were as follows:

i. The average yield from row planted plots was significantly higher than from adjacent broadcast plots -- that is, 766 kilograms per hectare compared to 434 kilograms per hectare.[31] Row planted plots were planted anywhere from two to 20 days after the adjacent broadcast plots, and targeted for good soil moisture conditions.

ii. The net gain to the host farmer from having his/her land row planted was estimated to be P64.49 per hectare.

iii. For the custom-hire operators, the row planting operation took on average 6.17 hours per hectare, which at the ARAP subsidy level of P20.00 per hectare, amounted to a return of P3.24 per hour.[32]

iv. Unfortunately no mechanical weeding was undertaken as the custom-hire operators were occupied with row planting.

(c). ***Recommendations.*** The inability of the custom-hire operators to implement the mechanical weeding operation implies the need to:

i. Encourage supplemental winter feeding of the draft animals of the custom-hire operators, to improve their condition for early and rapid row planting, and to encourage farmers to plow (i.e., prepare) their land early.

ii. Provide double row planters for use by custom-hire operators to further reduce the row planting time per hectare.

In conclusion, it seemed that custom-hire row planting, and possibly custom-hire mechanical weeding, could have a role to play in helping farmers who did not have enough resources, or lacked the skills to do it themselves. Realistically, however, such an approach would only be likely to succeed if subsidies were targeted to encouraging row planting and mechanical weeding.

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30. Out of 42 farmers who initially expressed interest in the row planted scheme.

31. There is little doubt that the training program and the substantial amount of row planting done by each custom-hire operator during the planting season -- in a sense accelerating their learning or skill curve -- contributed to the significance of the results.

32. This does not include expenses incurred with reference to depreciation on animals and equipment, and time spent in moving from one field to another. Nevertheless, the return would seem to be quite attractive compared with the drought relief wage rate, prevailing at the time, of P2.48 per eight hour day.

4.4.4 WEEDING

4.4.4.1 Justification

Weeds are a factor that must be addressed in any dryland crop production system. When ATIP began research activities in the Central Agricultural Region and the Tutume Agricultural District, little work had been done to quantify the magnitude of this constraint to production in these areas. Thus initially studies and trials were conducted to better define the situation. The potential impact of weeds on crop production varied from season to season and depended on a number of factors including:

(a). The level and distribution of rainfall.
(b). Soil type.
(b). Tillage system employed.
(c). Quantities and species of weeds initially present.

Much of the ATIP initiative in weeding related activities has, of necessity, been one of responding to opportunities and perceived needs of others. For example, during much of ATIP's existence there has been below average annual rainfall, consequently farmers have not viewed weeding as a major problem. However, the activity still required considerable labor, and there were indications that some people had difficulty using the recommended weeding equipment. Thus some time was devoted to testing light weight cultivators that could improve the efficiency of the weeding operation in row planted crops.

The effects of different tillage systems on weed control have been discussed earlier (Section 4.3.2). This section summarizes descriptive work that examined traditional weed control systems and discusses observations on the FMFI testing of a new, light weight mechanical weeder (Maun cultivator).

4.4.4.2 ***Results And Conclusions.*** A summary of the results and conclusions is as follows:

(a). ***Hand Weeding In Broadcast Planted Plots.*** A Baseline Survey of farmers' practices in the Tutume Agricultural District was conducted in 1985 [ATIP RD 85-1, p. 8.11; ATIP WP 3]. This survey involved interviews with over 200 randomly selected farmers across the district. The results indicated that all farmers in the district broadcast planted at least part of their fields each year, while only four percent row planted some portion of their fields. The same survey showed that 75 percent of all fields were weeded by the female household members without help from males or non-household persons. Thus the indications were that in the vast majority of cases, weeding of crops was done by hand, by women. Generally crops were weeded only once.

Early diagnostic trials in Francistown indicated that weeds were not a major crop production constraint, at least during the dry years prevailing at the time, and that a single weeding was sufficient to achieve good weed control [ATIP WP 5, p. 10].

From 1986 onwards, weeding time per plot was measured by a stop watch in all researcher-managed (RM) trials in the Francistown region. This was done to allow for the calculation of partial budgets for technology comparisons. Virtually all of these RM trials contained traditional check plots with broadcast planted plots measuring 400 square meters in size. These weeding labor data indicated that hand weeding of single plowed, broadcast planted plots varied from 15 to 42

person-hours per hectare [ATIP MP 87-7; ATIP MP 87-9].[31] These figures varied widely depending on the factors mentioned above, for example level and distribution of rainfall. Where crop stands were very poor, or the plants suffered severe stress, farmers abandoned the crop and did not weed at all.

(b). ***Maun Cultivator In Row Planted Crops.*** In early 1988, the MDP personnel demonstrated a light weight mechanical weeder they had developed and manufactured in Zimbabwe. Previous field observations in the Tutume Agricultural District had suggested that farmers had difficulty in using the Mahon cultivator because it was heavy and therefore had a high draft requirement. It seemed that farmers had problems controlling the number of animals required to pull it when they had crops growing in the field. Furthermore, because they could not lift it out of operation, they were likely to lose crops whenever the animals strayed out of the rows. The Maun cultivator, on the other hand, could be pulled by one or two donkeys, and could easily be lifted out of operation if the animals strayed out of the rows. It was therefore decided to present the Maun cultivator to farmers in the Tutume Agricultural District and to observe their reaction.

The Maun cultivator was introduced to the ROFGs (Section 3.2.2) in the 1988-89 season. Though only a few farmers tested the machine, reaction was generally favorable. In the 1989-90 season, the Maun cultivator was again made available, for testing, to farmers in the ROFGs. The testing program was also extended to the EOFGs in Tati District (Section 3.2.3) because of the greater use of row planting among those farmers. At the same time it was introduced to farmers in the ATIP villages in the Mahalapye area.

The reaction to the machines in the EOFGs was immediately enthusiastic, with numerous farmers requesting to purchase the machines. In response, the ALDEP program allowed a trial sale of machines obtained from Maun. Twenty machines were obtained, and 16 were immediately purchased by EOFG participants through the ALDEP subsidy program.

4.4.4.3 ***Recommendations.*** There are a number of recommendations that can be made concerning the Maun cultivator. These are as follows:

(a). Though the response by farmers to the Maun cultivator was very encouraging, a follow-up study still needs to be carried out. The farmers who purchased the machines should be interviewed to quantify how much use they made of them, their opinions on the effectiveness of the machines, and any observations they might have on how the machines could be improved. The farmers in the EOFGs can be identified through the ADs in Mapoka and Musojane villages.

(b). It should be noted that the FMDU at Sebele still has some reservations about the machine, and some ideas regarding the improvement of the soil-engaging parts of the machine. These ideas should be developed and tested under farmer conditions.

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[31]. In comparison, very limited data for mechanical inter-row cultivation in row planted plots indicated that 8.5 draft power hours per hectare were required [PR G90-2, p. 4]. However, this figure did not include intra-row cultivation which has to be done by hand. Also two or three persons are required to operate the draft team.

(c). Within both the ROFGs and EOFGs, farmers using the machines have encountered some difficulty in adjusting them, and have requested more intensive courses on how to adjust and use the machines. Such farmer training courses should be developed once the machines are available for sale.

(d). Farmers have also observed that the machines do not work well on dry soil or where the weeds are "large". They have noted that the width of the machine is not adjustable. Therefore, when cultivating between fairly wide rows, it is sometimes necessary to go over the row twice to achieve good weed control. Before the machines are made available to farmers, steps should be taken to ensure that buyers are aware of these limitations. A **Promising Guideline** has been prepared [ATIP RP 6, Section 2.2.3] and later an **Agrifact** should also be produced. These should be distributed to ADs, and the ADs should advise potential buyers of these limitations before the machines are purchased.

4.5 SEMI-PERMANENT FIELD DEVELOPMENT

Increased rainfall retention and storage in the soil has been the objective of rainfall run-off management work. In some cases, this included the concentration or harvesting of rainfall run-off during storms, using semi-permanent soil structures or plowing patterns. In general, the options described in this section are proposed as alternatives to improved conventional tillage options which also assist in rainfall management. In the rainfall run-off management work, the semi-permanent systems can be differentiated on the basis of whether the management is of rain falling in the cultivated plot (in situ or micro-catchment) or for harvesting water from off the field (macro-catchment water harvesting). Basin flooding is the only system that ATIP has investigated that falls into the macro-catchment category.

4.5.1 RAINFALL RUN-OFF MANAGEMENT STRATEGIES

4.5.1.1 Contour Strip Cultivation[14]

(a). ***Justification.*** Contour strip cultivation was first proposed by visiting agronomists from the USA during the drought season of 1984-85. It was designed to address two problems of arable agriculture in eastern Botswana:

i. Many farming households face a plowing resource constraint. Because plowing in strips can more quickly cover a large area of the field, a greater portion of the field can be made receptive to rainfall infiltration earlier in the season.

ii. Since soil moisture is often limiting for crop growth, crop production often fails, even on land that has been plowed early. Strip cultivation improves the reliability of soil moisture because water infiltration in the plowed strips includes water harvested from the fallow strips. This harvested water could mean more reliable quantities of soil moisture available for crop growth.

The initial objective of testing contour strip cultivation was to evaluate this

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[14]. In some of ATIP's work this has also been called band or contour band plowing.

plowing system in terms of:

i. Water conservation.
ii. Grain yield per unit of land area.
iii. Grain yield as a return to plowing input.
iv. Grain yield per unit of labor input.

Following the identification of several problems with the system when implemented at the level of resource poor farmers, research focused on problem solving and technology design or modification. Objectives of the design phase of research on contour strip cultivation were to evaluate plowing and planting patterns that would:

i. Minimize the weed control problem inherent in the system.
ii. Improve water retention.
iii. Provide tilth for adequate plant establishment.

(b). ***Results And Conclusions.*** Contour strip cultivation has been included in RMRI testing for five seasons at Mahalapye, and three seasons at Francistown (Table 4.13). Even though testing of this system has been handled in researcher implemented trials, the way it has been implemented corresponds closely to the way most farmers would manage such a tillage system on their own. A group of farmers has also assisted in assessing the research work on contour strip cultivation at Mahalapye.[35] Several problems have surfaced in the implementation of this system.

During the first two years of testing, the strip system was not implemented directly along contour lines. This certainly limited the amount of water harvested by the system. Under these conditions, the strip system generally failed to produce as much grain per unit of land area plowed as was obtained from continuous plowing. Because of a weed control problem in the fallow strips, the return per hour of weeding labor input was also lower than for standard plowing [DAR, 1987, p. 101].[36]

Several design problems were identified in the early evaluations of strip cultivation These problems included:

i. Difficulty in controlling weeds in the fallow strips.
ii. Erratic plant establishment in the cultivated strips.
iii. Poor tilth associated with the edges of cultivated strips.
iv. Erratic concentration of water. Water failed to concentrate on the strips when slopes were not regular or large enough, or when the strip was not bounded by a furrow to collect and hold water so that it could infiltrate. Without a collection furrow, run-off water tended to flow through the cultivated strips.

Beginning in the 1987-88 season, cultivation strips were carefully laid along contour lines in both Francistown and Mahalapye. This change was made to

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35. See Section 3.2.1 for a discussion of how farmers can be used in evaluating RMRI trials.

36. This can be concluded by dividing the grain yields in Table 5 [DAR, 1987, p. 101] by the number of hours weeded.

TABLE 4.13. ATIP ACTIVITIES RELATING TO RAINFALL RUN-OFF MANAGEMENT STRATEGIES

MAJOR FOCUS	MORE DETAILS	YEAR[a]	AREA	SAMPLE[b]	TYPE[c]	TRIAL	ATIP PAPERS		
Contour strip cultivation	Tillage system trial	1985-6	F'Town	2,2	Trial	RMRI	RD 86-1, p.96-98 PR F87-8	RD 87-1, p.II.68-70	PR F86-5
	Water conservation systems trial	1985-6	Mahal.	3,3	Trial	RMRI	RD 86-1, p.57-59	RD 87-1, p.II.35-38	
	Water harvesting trial	1987	F'Town	3	Trial	RMRI	RD 88-2, p.57-58		
	Rainfall run-off management study	1987-9	Mahal.	4,4,4	Trial	RMRI	RD 88-2, p.41-42	RD 89-2, p.54-56	
Water conservation terraces	Rainfall run-off management study	1987-9	Mahal.	4,4,4	Trial	RMRI	RD 88-2, p.41-43	RD 89-2, p.54-56	
Ridge and furrow	Rainfall run-off management study	1987-9	Mahal.	4,4,4	Trial	RMRI	RD 88-2, p.41-43	RD 89-2, p.54-56	
Basin flooding	Water harvesting	1986	Mahal.	2	Trial	RMRI	RD 87-1, p.II.34-35		

a The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season, and 1984-5 refers to both the 1984-85 and 1985-86 cropping seasons.

b Refers to the number of sites or farmers. RMRI trials will usually have more than one replication at each site. Figures in the column separated by a comma indicate sample sizes in different years.

c. This can refer to a study, survey, trial or paper.

determine whether this would increase the amount of water harvested by this simple technique.

Double plowing and broadcast had been used to till and plant the cultivation strips. With this planting method, plant establishment continued to be erratic. Plants often were not established at points where water was harvested. The other major problem was weed control. Early hand hoe weeding at Mahalapye required a great deal of labor. A weed slashing technique was tested at Francistown, but this still required a large amount of labor [ATIP PR F88-6].

In the following two seasons, work on the design of contour strip cultivation was continued at Mahalapye only. Several changes were made in the design of the strip system. A group of farmers was convened at the end of each season, in a workshop format, to discuss the strip system and to provide advice on ways this system might be improved and made more useful for farmers in the area.

Design criteria for the contour strip cultivation system were as follows:

i. Plowing of the strips were to be done as early in the season as possible.

ii. Strips were made by plowing two or three passes in each direction. In this way, a strip with a slightly raised ridge running along the center was created.

iii. With this pattern of plowing, dead furrows were left at both margins of the cultivation strip which served as collection furrows for run-off from the fallow strips.

iv. Strips were to be placed as close to the contour lines as possible. However, it was observed that the lateral movement of water was generally minimal.

v. Cultivation strips were to be placed so that no more than one meter of fallow separated them. Farmers indicated that this was the maximum width that most farmers would be willing to weed.

vi. Weeding of the fallow strips was to be done by early hand hoe weeding or by using a harrow.

vii. Following a useful planting rain, strips were to be row planted. Row planting helped to ensure a better placement of plants and a more reliable plant establishment. Reliable plant establishment was very important in this system given that a large part of the field was not seeded.

viii. Each cultivation strip had to be wide enough so that row planting could be accomplished without putting seed near the edges of the strip. It was observed that rows planted near the dead furrow suffered from water logging.

ix. The position of the strips was intended to be permanent, with plowing always following the same pattern year after year. The advantages of permanent placement of strips were that contour lines did not need to be re-established every year, that soil building amendments were concentrated in the strips, and production strategies such as crop rotation were readily managed.

Even though a number of problems with the design of contour strip cultivation have been solved, the system has not demonstrated yield benefits over conventional

cultivation, or improvements in return to plowing or labor. Generally, farmers have expressed concern with the notion of leaving cleared land uncultivated, with the weed control problems of this system, and with the idea of intentionally concentrating water at points on the field.

(c). ***Recommendations*** A **Promising Guideline** has been produced since more extensive testing of the system would be desirable [ATIP RP 6, Section 2.1.2]. However, no final decision has been reached as to what research should do with the contour strip cultivation system. In general, agricultural officers have expressed more interest in this system than have farmers. The advantage of contour strip cultivation is that it is simple and could be implemented by nearly all farmers with existing resources.

Specific areas where further research could still be useful are:

i. Use of permanent vegetative cover in fallow strips. Farmers expressed concern with leaving weed and grass growth in the fallow. They cited the problem of pests being harbored in vegetation of such a large number of strips in the field. On the other hand, agro-forestry and soil conservation advocate such measures. Research could look at the benefits and detrimental effects of leaving grass strips, or other vegetative cover, on the fields in Botswana, so that this information could be passed on to farmers.

ii. A type of relay cropping has been discussed for the strip system. Initial planting would be, as proposed for the cultivation strips, a means of conserving and harvesting rainfall. If the season were a wet one, fallow areas could be subsequently plowed and planted as well. This could solve the problem of weed control in the fallow areas in a wet year.

4.5.1.2 Water Conservation Terraces

(a). ***Justification.*** A design for water conservation terraces has been evaluated and modified during three seasons of the Rainfall Run-off Management Study at Mahalapye (Table 4.13). This design was adapted from a high precision design that was developed for the semi-arid Great Plains of the USA.

Part of the justification for working with water conservation terraces in Botswana came from observations and analyses that particular sites within the landscape have the highest yield potential during both drought and high rainfall periods [ATIP EP 89-3; ATIP MP 88-6; ATIP RD 88-2, pp. 40-41]. Water conservation terraces have been proposed as a technique for creating high potential zones within a field. These zones are characterized as areas with water run-on potential and with deeper soils (i.e., water holding capacity).

The objectives of the work on terraces with limited resource farmers, were to develop appropriate procedures for developing the terraces, and satisfactory planting methods for use on them. In this context, tilth for planting was a major issue. Weed control in the terrace system would be no different than for the traditional plow and broadcast system.

(b). ***Results And Conclusions.*** Development of water conservation terraces was planned to take place over a three or four year period. This type of implementation was

thought to be most appropriate for resource poor farmers who would not be willing to devote much more than normal tillage input, even initially, into the terrace system. In the first season, ridges, or other barriers, were built along the contour with 15 to 20 meters separating them. Subsequent plowing was always in the direction of moving soil to the ridge. In this way, an eventual build-up of soil occurred above each ridge creating a zone with deeper soil, and provided there was sufficient slope, some water run-on potential. After two seasons, there still was not enough soil movement to complete construction of the terraces. Therefore, the agronomic results do not reflect the potential of this system. Following the advice of farmers, the terraces were double, and in some cases, triple plowed following the second season, in order to complete construction of the terraces. Thus, the results in the third season were confounded with the effects of early plowing. However, the comparison of terraces and early plowing with double plowing was valid.

Specific results from this system were as follows:

i. Plant establishment was generally good within the terrace and was often better than the double plowing comparison.

ii. Water run-off leading to channeling and originating in the terraces was less than channeling from flat cultivated areas elsewhere in the field.

iii. The construction of the terraces was more definite and results more promising on land with slopes of 1.2 percent or greater.

iv. There was a definite soil build-up at lower portions of terraces following four rounds of plowing.

v. Farmers indicated an appreciation of the concept of water conservation terraces.

vi Weed control and other management issues were no different than for flat cultivation.

vii. Two elements of the terraces were difficult or costly, namely:

-- The construction of base ridges for each terrace required the use of good traction on days with adequate soil moisture. Many farmers felt that this work would have to be done with a hired tractor.

-- The plowing pattern involved plowing in one direction through the entire terrace until a satisfactory bench was created at the lower zone. Once the bench was created, plowing could again be done as usual, provided there was no drastic movement of soil within the terrace.

Agronomic and economic results from the water conservation terraces were not conclusive. This system would need to be tested over a range of seasons.

(c). ***Recommendations.*** In addition to the **Promising Guideline** which has been produced [ATIP RP 6, Section 2.1.3], recommendations are as follows:

i. Research should be continued, but in more of a farmer implemented mode

for farmers who are interested in participating. Research should provide a consulting service and monitor the results.

ii. Some type of vegetative cover for ridges should be investigated.

iii. The possibility of adding soil amendments to the high potential zones of the terraces should be investigated, and the results should be monitored.

iv. The Development Trusts of Shoshong and Palapye should be assisted in the demonstration and extension of water conservation terraces.

4.5.1.3 Semi-Permanent Ridge And Furrow

(a). ***Justification.*** Large semi-permanent ridges and furrows were introduced into the Rainfall Run-off Management Study by the Land and Water Management Project (LWMP), under SACCAR, headquartered at Sebele. The purpose of introducing the ridge and furrow system into the ATIP program was to observe its implementation on a relatively extensive (i.e., typical farm) scale. This work paralleled and complemented the more intensive management of this system by the SACCAR group at the Gaborone, Mankgodi and Sebele sites.

The semi-permanent ridge and furrow system was an elaborate and costly system, intended to increase the reliability of production in drought prone regions by permitting no net run-off from cultivated land, and by concentrating in situ rainfall in the rooting zone of wide rows spaced at 1.5 meters.

The specific objectives of ATIP research on this system were to:

i. Evaluate the implementation procedures and their appropriateness for small farmers.
ii. Evaluate planting methods and investigate the issue of creating tilth for plant establishment in the system.
iii. Obtain farmer assessment of the system.

(b). ***Results And Conclusions.*** The ridge and furrow system was expensive to implement in the first year. Farmers indicated that initial implementation was too costly unless the system yielded dramatic benefits. Even then, the ridge and furrow system was more likely to be used on a small-scale for higher value crops (i.e., maize for green mealies) than for sorghum which had been used in the assessments.

Implementation involved the following steps:

i. Plowing the land.
ii. Ridging with a special ridging tool usually drawn by a tractor.
iii. Compacting and then reshaping the ridges.
iv. Possibly cultivating the flank of the ridge before planting.
v. Planting mechanically which was difficult, or by hand.

After the first season and when the ridges were well established, no further tillage was planned. Instead, the ridges were re-shaped. This served to loosen the soil on the flank of the ridge for planting and gave some measure of weed control. Re-

shaping was followed by planting.

In addition to the cost of implementation, two major problems that were identified were: plant establishment and root development.

Planting in the system was done on the flank of the ridge. However, because this flank was prone to rapid drying, plant establishment was erratic. The most successful establishment came from hand planting using hoes or similar hand tools. Several planters -- including a single row planter, a hand jab planter, and the rotary injection planter -- were investigated as to their practical application on a field level. However, none of these were satisfactory for planting on the flank of ridges.

Once plants were established, root development on the untilled flank was impeded. Roots tended not to penetrate to stored soil moisture.

(c). ***Recommendations*** Even though soil moisture monitoring indicated that moisture was retained in the ridge and furrow system, this system has not successfully improved crop production. The current design needs no further testing on farmer's fields. ATIP recommends to the Land and Water Management Project that the system be re-designed to improve tilth in the planting area. A proposal to accomplish this is to convert alternate ridges of the current design to flat beds that could be tilled and planted. This new design would reduce the amount of water concentrated, but would greatly improve the possibility of achieving satisfactory plant establishment and root development.

4.5.1.4 Basin Flooding

(a). ***Justification.*** Basin flooding was an idea that emerged from discussions with consultants of the Soil Management Support Services (SMSS) in 1985. Earlier, ATIP researchers had held exploratory talks with farmers about developing improved small dams to impound water run-off during large storms. The SMSS group advised that water could be more efficiently used by resource poor farmers by using the water holding capacity of the soil profile as the storage reservoir.

Basin flooding is an ancient technique used in the Middle East and the Indian Sub-Continent to harvest rainfall run-off from watershed areas above a field (macro-catchment) and to wet the soil profile of the field whenever rainfall run-off events occur. The incidence of large rainfall events (e.g., that would produce run-off) in Botswana is noteworthy [ATIP MP87-3].

The need for higher levels of soil moisture to improve crop yields and to increase the reliability of yield, particularly in drier years, is evident in the case of Botswana. What is not clear is the extent to which an intervention like macro-catchment water harvesting to flood basins on the field will give dividends in eastern Botswana. This technique has generally been applied in zones that receive less rainfall than the 465 millimeter annual average for Mahalapye, Botswana. Water harvesting techniques are also utilized in areas where farmers devote more time to the intensive management of the arable enterprise than is the case for most households in Botswana. This may create problems since male labor in Botswana is often used for the management of livestock and off-farm employment, with only a small portion allocated to arable operations.

The objectives of this study were to:

i. Evaluate site selection criteria for water run-on potential and suitability as a water harvesting production site.

ii. Test simple structural developments on the field that would enhance water run-on (supply channels) and water retention (retaining bunds).

iii. Assess farmer response to the technology and to the management issues involved.

iv. Assess the risk of increased erosion created on the field.

v. Measure the benefit of water run-on in terms of cropping outcomes.

vi. Evaluate the return to other production inputs (double plowing, phosphate fertilizer, stover incorporation) at the water run-on sites.

(b). ***Results And Conclusions.*** A summary of the major results is as follows:

i. Using the experience of host farmers, nine sites in different fields were identified as having water run-on potential. During the season, six of these were classified as water run-on sites. Such field sites also tended to have deeper soils and deposition of clay in the sub-soil resulting in a higher water holding capacity.

ii. With the assistance of the Soil Conservation Unit, MOA, supply channels and water retaining bunds were constructed on two sites that had water run-on potential. Results from developments on these two sites were inconclusive. When significant water run-on occurred naturally, the channels and bunds contributed little to controlling the movement of water. These bunds were substantial -- 50 centimeters in height -- which indicated that the design requirements for adequate structures would be considerable. Distribution of water in the bunded parts of the field was not very good.

iii. Farmers participating in this study cooperated fully, but expressed no interest in promoting water run-on to the field. Rather, interest was expressed in using bunds to divert flood water around the field. Farmers also indicated that the management of gates for the supply channels, that could be closed to prevent further water from entering the field, would be difficult because farmers were often not at the fields and during storms would not want to venture out to far corners of the fields.

iv. Erosion occurred during storms on all water run-on sites. Except for scouring in the supply channels, there was, however, no evidence of an increase in the risk of erosion, in the sites with water retaining bunds. It was clear, though, that the quantity of water flowing onto many fields could not be retained in a manageable way using the techniques of this study.

v. The benefit of water run-on for cropping outcomes is discussed elsewhere [ICAR, 1988 pp. 107-108]. Grain yield at water run-on sites was significantly higher than at other points of the field but was not improved by the addition of water harvesting structures.

(c). ***Recommendations.*** In the 1986-87 season, ATIP made a decision not to continue the work on water run-on enhancing techniques.[37] This was because of the assessment that even though basin flooding could work technically, most farmers were not prepared to accept the management required. Also the system increased erosion hazards. Instead, the decision was made to focus on the management of **in situ** rainfall and to develop recommendations for the management of natural run-on sites (see point (c) "iii") under Section 4.3.3.2).

A decision was also reached to consult with agricultural hydrologists about flood control measures for individual farms and/or communities sharing a watershed. Other researchers, who have been consulted, feel that most field situations do not warrant additional flood protection given the anticipated level of production. A conflict of interest is apparent between researchers who tend to be concerned with improving crop production through water conservation and water concentration, and many farmers who accept the risks of erratic rainfall and see a major hazard in flooding. Research staff and the Soil Conservation Unit in MOA need to look more carefully at the issue of flood protection.

If sufficient resources were available, it would be recommended that a study be undertaken to assess the long-term potential benefit of water harvesting for Botswana. This study could be based on a simple model incorporating rainfall probabilities for periods within the season, water holding capacities of different soil-types, and estimated crop requirements. The main issue would be whether priority should be placed on water concentration to improve the reliability of production, or be placed on improving in situ rainfall use efficiency.

4.5.2 SOIL FERTILITY ISSUES

4.5.2.1 Use Of Fertilizer And Kraal Manure

ATIP observed that most farmers in the research villages knew of chemical fertilizers and the use of kraal manure. Even though some distinction was made between chemicals and manure, farmers tended to group all classes of fertilizer together. They were generally referred to by the same name. Farmers did not differentiate between the different types of chemical fertilizers.

A summary of how often chemical fertilizers were used is given in Section 4.3.4.1. Only a few farmers had ever tried to use fertilizer and nowhere was it used on a regular basis. Not only was it rarely used, a majority of farmers indicated that they lacked knowledge on the effects of chemical fertilizer. The use of chemical fertilizer was low in both the Mahalapye and Francistown areas, even in villages where other improved methods were used [ATIP RP 1, p. 67].

The use of chemical fertilizer was also not generally listed as a promising practice by farmers [ATIP RP 1, pp. 60-70]. On the other hand, ADs ranked fertilizer use just behind row planting as a practice with potential to improve grain yield [ATIP RP 1, p. 71].

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[37]. The work on basin flooding has, however, been continued by INTSORMIL [Carter and Miller, 1990].

Comparisons with chemical fertilizer have often been part of the village level demonstrations set out by the ADs. The ADs listed lack of knowledge, lack of labor and concern with weeds as the main reasons farmers failed to use fertilizer.

The use of kraal manure followed a similar pattern. Little manure was used in either ATIP research area [ATIP RP 1, p. 68; ATIP RP 2, p. 41). Even though some farmers indicated that they believed manure and chemical fertilizer would increase yields, others said they were not certain or did not know how to apply a chemical fertilizer or manure amendment to the soil.

There was some indication that farmers did not perceive that low soil fertility was an important limitation to improved yields. Poor soils or low soil fertility was clearly ranked below many other perceived problems [ATIP RP 2, p. 51].[38]

The use of fertilizers was also limited by the cost. Capital outlay for a recommended phosphate fertilizer application of four bags of single phosphate (approximately 20 kilograms of P per hectare) was P93.20 in 1990. Even the application of manure required transportation and manual labor (see Section 4.5.2.4). Farmers feared that more weeding would be required on fertilized plots.

The indifference of farmers towards fertilizers was illustrated when ARAP fertilizer was made available free of charge to farmers. Most farmers in the research areas failed to pick-up the free fertilizer. For those who did, many didn't use it. Only a few farmers chose to apply the free chemical fertilizer. Where it was used, the application tended to be on small plots.

4.5.2.2 Land Use Changes And Soil Fertility

A summary of soil fertility information is given in Section 4.3.4.1. Typical chemical properties of soils in the Mahalapye area were assessed to be marginal for crop production [ATIP RP 1, p. 157].

In most years, rainfall was the most limiting factor. It was only in years of higher rainfall that the limitation of poor soil fertility was exposed.

Under two situations, the arable land use pattern could change to more intensive management which, in turn, could affect soil fertility and the influence soil fertility has on productivity. Such a change may occur because of increased pressure on land or because of the need to find methods that would result in a better return to labor input:

(a). The purpose of the History of Cultivation Study [ATIP RD 89-2, p. 108-109] was to assess the development of cultivation in Mahalapye research villages. The study (unpublished information) showed that the pressure on land had increased. Since 1963, the area cleared for cultivation in each farm increased as did the number of farms. Increases in field size occurred even before government programs subsidized land clearing and the expansion of cultivation. Both farmers and agricultural officers recognized the logistical problems -- the distance between fields and villages increased, and sometimes there was shortage of water in more remote areas -- created by the expansion of cultivation.

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38. This was also derived from unpublished information in the History of Cultivation Study [ATIP RD 89-2, pp. 108-09].

(b). The traditional method of production resulted in low returns to labor. With low yields in drier seasons, this return[39] was sometimes negative [ATIP RP 1, pp. 78, 81-87]. Much of the ATIP work was on intensifying tillage and planting. Use of new methods sometimes resulted in a reduction in the area cultivated, while at times, yields and the return per hour of labor input did improve (e.g., double plowing [ATIP MP 87-6]. As was expected, the likelihood that soil fertility limited productivity increased as more improved tillage methods were used by farmers (Section 4.3.4).

4.5.2.3 Summary Of Chemical Fertilizer Trials

The justification for the work with chemical fertilizers is discussed under Section 4.3.4.1. The project decided that there was little justification in working with fertilizer application per se. Most research involving fertilizer was with the objective of assessing the interaction of tillage and planting methods with a recommended rate of phosphate fertilizer. In most cases, this involved a "with" and "without" comparison.

In only two trials, were different levels of fertilizer applied. The High Potential Site Trial in 1986-87 [DAR 1988, pp. 107-108; ATIP RD 87-1, p. II.24-II.26] involved two levels of P. The High Potential Site trial in 1987-88 involved P at 20 kilograms per hectare and P plus nitrogen [ATIP EP 89-3]. These two trials are also discussed under Section 4.3.4.2 points (d) and (e).

The most profitable responses to chemical fertilizer were from the use of P plus nitrogen at selected high potential sites in a wet year, and the response to the recommended rate of P under improved tillage and planting on deep soil profiles (see Section 4.3.4.2 point (c)).

Another objective of work with fertilizer was to demonstrate their use to farmers and seek feedback that would be useful for further research and extension. Use of phosphate fertilizer was demonstrated in a superimposed trial [ATIP RD 83-1, pp. 7.32-7.33; ATIP RP 1, pp. 174-175; Section 4.3.4.2 (a)] and in ROFGs [ATIP PR F87-6, pp. 7,9]. The use of phosphate under farmer implementation was not profitable. However, as an extension exercise, the demonstration was useful as it provided farmers with information about phosphate and allowed them to assess its use first hand.

4.5.2.4 Kraal Manure -- Resource Assessment

(a). ***Justification.*** During most of the ATIP research period, little work was done with kraal manure. The decision not to work with manure was based on indications that farmers faced several important constraints. One of these constraints was the fact that manure was not readily available [ATIP RP 1, p. 69]. This finding is contrary to conventional wisdom and assessments made by other researchers working in Botswana [Herbert, 1983 pp. 10, 13].

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[39]. The need for a better return to labor is acute. In wetter seasons, extensive cultivation often outpaced labor available for weeding, bird scaring and sometimes even harvesting. This again limited the return to labor in years that had good potential. The labor shortage will continue to worsen as individual members of households move away from the villages, to seek jobs.

The need to study the availability of manure became important after researchers in the project decided to look at ways soil fertility could be enhanced for situations where tillage, planting and water management were improved (see Section 4.5.2.2). A resource assessment study [ATIP RD 89-1, pp. 52-53] was conducted with 29 farmers, in conjunction with a trial on crop responses to manure under farmer management (Section 4.5.2.5). Both studies were designed to provide baseline data not previously available in Botswana. The specific objectives of the resource study were to:

i. Gather farmers' assessments on the relative merit of manure use versus other options that could also improve soil fertility.

ii. Assess the availability of manure on a household basis. Availability was broken down into whether access to any manure existed, the quantities available and where the manure was located in relation to fields.

iii. Assess the availability of transportation and labor for the application of manure.

(b). ***Results And Conclusions.*** Farmers stated, overwhelmingly, that they would prefer to use manure over chemical fertilizers. Even though most farmers had never used it, they preferred manure because no cash outlays would be required.

Because of possible problems of weed seed importation, farmers said they would prefer cattle manure to goat manure, and manure from abandoned and older kraals. They envisaged using the old manure on a small-scale basis (i.e., garden plot size or areas of no larger than a hectare).

About 70 percent of the farmers surveyed felt they had ready access to manure. This group of farmers felt that they could obtain manure either from kraals they owned or from those of neighbors and friends. It was generally felt that manure could also be purchased locally. No actual large-scale market existed but, if it did, it was estimated -- based on 1989 prices -- that it would cost P5.00 per two-wheel donkey cart and P20.00 per four-wheel donkey cart. Researchers felt that given the comparative capacity of these two carts, the cost per two-wheel cart load was underestimated and would be adjusted upwards if carting of manure became a commercial activity.

A typical situation for a farmer with access to manure was to own one goat kraal and own or otherwise have access to manure from one or more cattle kraals. The size of the kraals varied and therefore the amount available from any kraal also varied. Cattle kraals in the study tended to be considerably larger than goat kraals. The average area of cattle kraals was 270 square meters and the average measured quantity of manure was 19 tons (converted to dry weight). The average area of goat kraals was 54 square meters and the average measured quantity of manure was 7.6 tons (dry). These figures suggest that in a typical situation, a farmer would have direct access to 20 to 30 tons of manure. This amount of manure, which accumulated over several years, was clearly not enough to sustain applying manure, according to the official recommendation of 10 tons per hectare, every three years. An average field size was five hectares or more.

Goat kraals were located in the proximity of the village or fields. Distances between goat kraals and fields ranged from 0.5 to 5 kilometers. Cattle kraals tended to be

located further from the fields. Large concentrations of manure were available at distant cattle posts, that belonged to wealthy farmers. However, these cattle kraals were not sampled in this survey.

Inquiries into transportation dealt with issues of access to carts and the capacity of carts. One-third of the sample owned some type of cart. Most of these were four-wheel donkey carts. Almost as many farmers said they could borrow carts. However, easy or inexpensive access for the purpose of transporting kraal manure appeared to be seasonal. If manure were to be applied during winter, the use of carts would have to compete with transporting firewood, water and sand. The more established demand of these activities would increase the opportunity cost of transporting manure. Average cart capacity estimates were 0.6, 0.3 and 0.8-1.0 tons per load for four-wheel donkey carts, two-wheel donkey carts, and tractor trailers, respectively. With these capacities, the four-wheel, the two-wheel and the tractor drawn units would require 17, 34 and 13 loads, respectively, to apply 10 tons of manure.

Although male labor is available during the winter period, many households would need to hire help. Some farmers expressed concern that hired labor would work at very slow rates unless payment was on the basis of the number of loads transported. The work is very strenuous and time consuming. Work rates were estimated for crews, hired by the project, to transport manure farm trials. For example, to apply 10 tons per hectare, the following figures applied:

i. Loading averaged 22 person-hours per hectare.
ii. Transporting one kilometer averaged 17 person-hours per hectare.
iii. Off-loading[40] averaged 6.6 person-hours per hectare
iv. Spreading averaged 2.2 person-hours per hectare.

This 47.8 person-hours per hectare labor cost for applying manure did not include time added to weeding that might be required on fields to which manure had been applied.

(c). ***Recommendations***. These are as follows:

i. Until circumstances can be defined where the crop response is profitable and should be promoted to farmers, the current data on the availability of manure are sufficient as baseline information. Additional data should be collected to confirm the existing estimates on the cost of applying kraal manure.

ii. Clearly, agronomic research should focus on using small quantities of manure. The goal should be to use manure in defined cropping situations with a comparatively high potential for a profitable return.[41]

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[40]. Off-loading and spreading were calculated as separate activities because manure was left as a heap on the field until just before plowing so as to minimize nitrogen loss.

[41]. The cost of applying and the availability problem clearly preclude more than a few neighboring farmers from using manure on an extensive scale. If the demand for manure were to increase, and nearby sources of manure were depleted, transportation costs would greatly increase.

4.5.2.5 Kraal Manure -- Crop Response Trials

(a). ***Justification.*** The use of kraal manure has been tested in different trials in Botswana and generally the crop response has been favorable. All of these trials have been managed by researchers and presumably have involved a fairly high level of management. Herbert [1983, pp. 15-16] reported that under these conditions, the crop response to manure was not important in years with low rainfall. This result is somewhat unexpected because manure should increase water holding capacity of the soil and thereby improve production, at least for sandier soils, in relatively dry seasons. Carter, Harris, Youngquist and Persaud [1990] found that manure increased the water holding capacity in soils. They also reported that the use of manure gave a long-term grain yield benefit, produced residual benefits into years when additional manure was not applied, and was most effective on sandier soils.

Because of the opinion expressed by farmers, the use of manure as a general application on the farm was not tested in the early years of the project. Rather, a few trial activities concentrated on special production circumstances. More recently, ATIP researchers re-evaluated the manure issue and decided that there was sufficient justification -- based on the need to improve soil fertility as farmers shift to better tillage and planting practices (see Section 4.5.2.2), research station results, and the lack of baseline information on crop response to manure under farmer management -- to conduct further research.

The use of kraal manure has been tested in three ATIP trials. The specific objectives of these trials were as follows:

i. To evaluate the benefits of establishing a vegetable garden plot for home residences. Manure was included in the production package, but was not tested separately [ATIP RD 85-1, pp. 7.32-7.33; ATIP RP 1, pp. 199-200].

ii. To assess the impact of applying 14 tons manure per hectare to selected sites on farmers' fields. The selection of sites was based on farmer's observation that these areas received the highest water concentration. The test was under farmer managed crop production [ATIP RD 85-1, pp. 7.33; ATIP RP 1, p. 199].

iii. In an on-going trial, to run three seasons, 10 tons of manure is being applied, per hectare, every year, under farmer managed crop production conditions. The objective of this trial is evaluate the residual effects of manure application and targeting of manure use to contrasting soil-types [ATIP RD-89, p. 53-54].

(b). ***Results And Conclusions.*** A summary of the results is as follows:

i. The evaluation of garden plots at the home residences using manure was not successful. Several management issues were raised. However, ATIP researchers felt that the concept was appropriate and that recommendations on garden plots should be developed and promoted. This work was not pursued further by ATIP.

ii. During a very dry season, there was no crop response to manure at selected sites on field. Farmers showed little interest in using manure and this trial

was dropped. The trial did help to establish the principal of encouraging farmers to help target interventions to specific parts of the field or operation where the return might be most profitable. As in the case of manure, many interventions are too costly to be applied over the entire field.

iii. Two seasons of the current three year study on the crop response to kraal manure have been completed. Yield benefits, after one season were not significant. Similar results are expected after the second season. There was no indication of a residual benefit in this trial. Under farmer management, plant establishment was erratic and many fields were planted late, but overall grain yields were typical or better than for other farms in the area. The problems were, in part, a function of the poor rainfall patterns of these two seasons. The response to manure application is thought to accurately reflect what should be expected under typical management conditions. The results also failed to show a difference in response for sandy and finer textured soils.

iv. Clearly, the returns to the use of manure were not profitable. An economic break-even analysis is still useful to help understand the types of target benefits that would be required. A problem in the analysis is how to value the opportunity cost of transport and labor during dry season work. If it is assumed that the farmer owns a cart that is not being used (no opportunity cost) and labor is valued at 35 thebe per hour, the use of manure starts to be profitable with only 50 kilograms of grain per hectare benefit. If the opportunity cost of labor is on the order of P1.00 per hour, a benefit of 150 kilograms per hectare would be required. However, if the cart can be used profitably for other activities, the cost of manure use would increase greatly. For example, a load of firewood per four-wheel donkey cart could sell for P10.00.

(c). ***Recommendations.*** A summary of the recommendations is as follows:

i. Results would not suggest that a major emphasis be placed on the general recommendation that farmers apply manure over the entire field, every three years.[42]

ii. On-farm researchers should complete the current on-farm trial on the use of kraal manure.

iii. On-farm researchers should focus new research on the use of manure in special production situations. These situations could include tillage and planting methods, and water conservation systems in which the level of plant establishment or soil moisture is expected to be improved, and sole plots of high value crops such as groundnuts and cowpeas are grown.

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[42]. Ministry of Agriculture recommendations suggest that 12.5 tons of manure per hectare should be applied every three years [Herbert, 1983].

CHAPTER 5: COMMODITY INVESTIGATIONS

5.1 CROP COMMODITY INVESTIGATION ACTIVITIES

5.1.1 INTRODUCTION

The main body of agronomic research carried out by ATIP has focussed on the two major cereal crops -- sorghum and millet -- in local crop production systems. However, small-scale farmers in Botswana do produce a wide range of minor crops in addition to sorghum and millet (see Chapter 2). These minor crops can be important to the farmer as a source of nutrition, as a hedge against loss of the cereal crops, and as cash crops. ATIP has conducted some research on these minor crops because of the above reasons, and also in response to requests from station-based commodity research programs.

Since the main body of research has dealt with the major cereal crops -- sorghum and to a lesser extent, millet - this part of the report has been included specifically to present research conducted on minor crops. Therefore, the discussion below presents research findings on:

(a). Cowpeas (Section 5.1.2).
(b). Groundnuts (Section 5.1.3).
(c). Mung beans (Section 5.1.4).
(d). Sorghum-based intercropping systems (Section 5.1.5).

5.1.2 COWPEAS

5.1.2.1 Justification

A Cowpea Baseline Survey was administered to a large number of farmers early in the ATIP, in both the Mahalapye and Francistown areas [PR M84-5; PR F84-1]. This was done partly at the request of the station-based cowpea researchers. The survey indicated that cowpeas were grown by the majority of farmers in both areas,[1] largely in mixed-cropping systems, that most of the production was consumed at home -- both leaves and grain -- and that production was limited by a lack of seed, predation by pests, and the number of planting opportunities. Some sale of cowpeas was reported within villages, and later marketing studies indicated relatively high prices were received for cowpeas sold on the local market.

The widespread cultivation and consumption of cowpeas, and the relatively high prices of cowpeas in village areas indicated that cowpeas were an important crop. Because of this, some specific investigations on cowpea production were undertaken. These investigations, for the most part, were done in collaboration with the on-station commodity research teams, and included variety trials, potential of sole cropping, and improved planting methods.

These topics are discussed separately in the following section.

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[1]. In contrast, a much later survey on beans, also undertaken at the request of the on-station cowpea researchers, confirmed that beans were not important in the farming systems in the ATIP and FSSR areas [ATIP WP 24].

5.1.2.2 Results And Conclusions

A list of the activities specifically undertaken with respect to cowpeas is given in Table 5.1.

(a). ***Cowpea Variety Trials.*** Over the years, a number of cowpea variety trials were implemented. These were performed in collaboration with either the Seed Multiplication Unit (SMU) or the station-based cowpea researchers at Sebele.

Five out of the six sets of trials included comparisons of determinate and indeterminate varieties. In three out of those five trials sets, indeterminate varieties had a higher average yield than determinate ones. In the remaining two trial sets, the yield of at least one determinate variety was similar to the yield of the indeterminate variety. Thus in all comparisons of determinate and indeterminate cowpea varieties, on average, the indeterminate varieties yielded the same or better than determinate types.

In all years there were periods of drought stress and/or insect infestation that reduced crop yields. Several of the reports indicated that the higher yields of the indeterminate varieties were due to their capacity to survive stress periods and produce grain in more favorable periods.

These data indicated that under the difficult environments encountered in farmers' fields, indeterminate cowpea varieties were often the most productive. Determinate genotypes may be best suited to special niches in the cropping system, such as situations where late-season planting is required. All of the determinate cowpeas tested, in fact, were improved varieties, compared to the traditional varieties which tended to be indeterminate.

Although grain yield is an important evaluation criterion, the Cowpea Baseline Survey, referred to above, indicated that cowpea plants often had another purpose, namely, the leaves were used for human consumption. There is, of course, the potential for the residues to be used as feed for livestock. Consequently, in more recent years, the on-station cowpea researchers have recognized that the cowpea varieties should be evaluated in terms of being:

i. Single purpose -- grain yield.
ii. Dual purpose -- grain yield plus use of leaves for human food.
iii. Triple purpose -- grain yield plus leaves for human food and residues for livestock.

Based on ATIP's observations, in general, it would seem that indeterminate varieties are likely to be superior to determinate varieties in cases where farmers wish to have varieties fulfill more than one purpose. This is because:

i. Continuing leaf growth over a longer time period in indeterminate, compared with determinate varieties, means that leaves are available over a greater length of time. The issue of assessing the impact of leaf removal on grain yield in recent years has been investigated by station-based cowpea researchers at Sebele.[2]

ii. Leaf drop-off is more prolonged in indeterminate than in determinate varieties

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[2]. See for example, DeMooy and DeMooy [1989].

TABLE 5.1: ATIP ACTIVITIES RELATING TO SPECIFIC CROP COMMODITIES

MAJOR FOCUS	MORE DETAILS		YEAR[a]	AREA	SAMPLE[b]	TYPE[c]	TRIAL			
Cowpeas	Baseline survey		1983	Mahal.	49	Survey	---	RD 84-1, p.7.17	PR M84-5	
			1983	F'Town	275	Survey	---	RD 84-1, p.8.16	PR F84-1	
	Variety testing:	Grain yield								
	Tswana, Blackeye, ER-7, Sri Lanka		1983-4	Mahal.	7,11	Trial	RMFI	RD 84-1, p.7.23-35	RD 85-1, p.7.14	RP 1, p.202-204
	Tswana, Blackeye, ER-7, TVX 3236		1987-8	Mahal.	19,12	Trial	FMFI	RD 88-2, p.34-35	RD 89-2, p.49	
	Tswana, Blackeye, ER-7, TVX 3236, B005C		1987-8	F'Town	21,12	Trial	FMFI	RD 88-2, p.63-68	RD 89-2, p.88-90	
		Forage	1987	Mahal.	23	Trial	FMFI	RD 88-2, p.35		
	Sole cropping		1985	Mahal.	48	Trial	FMFI	RD 86-1, p.63-64		
	Planting method		1984	Mahal.	8	Trial	RMFI	RD 85-1, p.7.39	RP 1, p. 204-206	
Groundnuts	Sole planting		1985	Mahal.	7	Trial	FMFI	RD 86-1, p.63-64		
	Eliminating hilling		1987	Mahal.	17	Trial	FMFI	RD 88-1, p.37-38		
	Seed treatment		1984,86	Mahal.	11,17	Trial	RMFI	RD 85-1, p.7.41-42	RP 1, p.203 RD 87-1,p.II.47-48	
	Seed treatment		1967-8	F'Town	44,25	Trial	FMFI	RD 88-1, p.66-67	RD 89-1, p.89	
	Variety testing									
	55-437, Sellie		1988	Mahal.	12	Trial	RMFI	RD 89-1, p.49-50		
	55,437, Sellie		1988	F'Town	25	Trial	FMFI	RD 89-1, p.89		
	Row planting		1987-8	Mahal.	6,3	Trial	RMFI	RD 88-1, p.45-46	RD 89-1, p.59-60	
	Production package		1989	Mahal.	---	Trial	RMFI	RD 89-1, p.103		
Beans	Baseline survey		1988	Both	144	Survey	---	WP 24		
	Mung bean :	Crop variety comparison	1984	Mahal.	10	Trial	RMFI	RD 85-1, p.7.41-42	RP 1, p.202-203	
		Sole planting of crops	1985	Mahal	5	Trial	FMFI	RD 86-1, p.63-64		
Intercropping	Sorghum/cowpeas		1986-8	F'Town	6,6,6	Trial	RMRI	RD 87-1, p.II.73-74 PR F87-7	RD 88-2, p.52-53	RD 89-2, p.68-69
	Sorghum/melon		1987-8	Mahal.	12,12	Trial	FMFI	RD 88-2, p.33-34	RD 89-2, p.47	PR M90-1

a. The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season, and 1984-5 refers to both the 1984-85 and 1985-86 cropping seasons.

b. Refers to the number of sites or farmers. RMRI trials will usually have more than one replication at each site. Figures in the column separated by a comma indicate sample sizes in different years.

c. This can refer to a study, survey, trial or paper.

therefore improving the possibility of more leaves being harvested as crop residues, should an interest develop in storing fodder.[3]

In conclusion, it would appear reasonable, in view of the different uses of cowpeas, and the uncertainty of the growing season, that the farmer could benefit from selecting cowpea varieties based on their objectives, and the length of growing season remaining at planting time.

(b). ***Sole Cropping Of Cowpeas.*** A trial was conducted in 1985-86 in Mahalapye to examine the profitability of producing high value crops in sole stands [ATIP RD 86-1, p. 63].[4] The reason for doing this was that the management of mixed crop stands tended to be geared towards the dominant crop -- usually sorghum. Therefore the specific management of high value crops, such as cowpeas, in sole stands might make their production more profitable and increase the return to labor.

In general, the trial results were not very conclusive. They showed no major advantages or disadvantages to sole cropping. However, it was evident that farmers were not at all averse to planting high value crops in sole stands.

(c). ***Planting Methods Fo wpeas.*** A variety trial in Mahalapye [ATIP RP 1, p. 203-206] suggested that under the broadcast planting system, the variety ER-7 produced a lower stand density than other varieties. It was hypothesized that this could be due to smaller seed size. Subsequently, a variety by planting system trial was implemented to examine this hypothesis. In the second trial, results showed no differences in stand establishment between ER-7 and any of the other three varieties under either the broadcast planting system or where the planting was on plowed ground using a hand-jab planter. Furthermore, there were no variety by planting system interactions.

(d). ***Field Observations On Constraints To Cowpea Production.*** In general, over the years, the following constraints to cowpea production have been observed at the field level:

i. Draft power shortages and lack of planting opportunities.
ii. Difficulty in establishing good stands.
iii. Drought periods during the growing season.
iv. Major aphid infestations during dry periods. Aphid populations were greatly reduced after good rains
v. Major infestations of other pod-sucking insects, during years of above-average rainfall.
vi. Damage by rabbits and duikers.

The most frequently occurring problems have been items "iii" and "iv" above.

5.1.2.3 Recommendations. Recommendations for further work on cowpeas, which have included the production of a **Promising Guideline** [ATIP RP 6, Section 2.3.1] also includes

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[3]. See discussion in Section 5.2.2.3 on use of cowpeas in forage.

[4]. This was a follow-up of earlier work done on stand establishment and yields of cowpeas when grown in sole stands [ATIP RP 1, p.203].

the following:

(a). Cowpea variety testing should continue at the FMFI level, with emphasis on evaluating cowpea varieties for particular purposes, and their fit in particular niches -- for example, identifying better long-season varieties, and improved determinate types for late-season planting.

(b). Incorporating aphid resistance into acceptable cowpea varieties could have a major impact on grain yields at the field level.

(c). Farmers have shown a willingness to invest more effort in both cowpea and groundnut production, possibly because of their high value in local markets. This may indicate that the development and extension of more intensive production systems would be acceptable to farmers, providing they are reliable and more profitable.

(d). At present, seed of improved cowpea varieties is difficult for farmers to obtain. Efforts should be made to rectify this situation.

5.1.3 GROUNDNUTS

5.1.3.1 Justification

ATIP work with groundnut -- Arachis hypogaea -- is of particular interest because the crop was known, but not widely grown at the beginning of project work. Groundnut was essentially not grown by farmers in the Mahalapye research villages [ATIP RP 1, p. 60]. Groundnut was more frequently grown by farmers in the Francistown area but still not grown by most households [ATIP RP 2, pp. 39-41; WP 3, pp 2, 10-11]. This means that research involved devising ways to encourage farmers to produce the crop as well as conducting experiments on production methods. Another groundnut, jugo bean (Boanzeia subterranea), was more commonly grown in both Mahalapye and Francistown areas.

The primary reason for beginning on-farm research with groundnut stemmed from the desire to react to positive trial results from the station-based groundnut researchers. These researchers had begun to work on groundnut in 1983-84, and first results indicated a substantive improvement in stand establishment by treating seeds with fungicides. The interaction between oil seed and farming systems research illustrates the potential of a linkage that is mutually beneficial [see the **Promising Guideline** in ATIP RP 6, Section 3.2.1]. The groundnut commodity and farming systems research linkage involved the development of station or farm testing on at least five issues of mutual interest as well as regular field visits.

At the time the decision was made to work with groundnut, relatively little station work had been done. Groundnut is usually grown in parts of the world with more reliable and greater total rainfall than in eastern Botswana [Martin et al., 1976]. Still, estimates of grain yield potential for areas like Botswana appeared favorable. Pandey, Herrara, and Pendleton [1976] reported that groundnut could produce more than one ton per hectare on as little as 200 millimeters total rainfall in a season. Before 1982, groundnut yields from research trials were above 600 kilograms per hectare in 22 out of 31 season/locations. During four seasons (all wet) in Mahalapye prior to 1982, groundnut (variety Sellie) yield in on-station trials

averaged two tons per hectare.[5]

The objectives of on-farm research on groundnut included the following:

(a). To evaluate the incentives farmers had for producing groundnut.
(b). To evaluate the yield levels with conventional methods to help assess the potential contribution small farmers could make to production targets for the country as a whole.
(c). To evaluate measures that could reduce labor costs or facilitate management of groundnut production for small-scale producers.
(d). To evaluate methods to increase production by small-scale farmers.

5.1.3.2 Results And Conclusions. The following is a brief summary of the results.

(a). ***Observations On How Groundnut Fitted Into The Farming System.*** Even though only Spanish type varieties (determinate) were used in research, the crop was of a long duration (approximately 130 days for Sellie). It was observed that the crop was sensitive to cool temperatures, therefore, it was necessary for the farmer to have land prepared and planting done before mid-December. The determinate growth habit made the crop reliant on soil moisture at critical times (i.e., from bloom to just before harvest). The relatively long maturity cycle gave little flexibility in terms of planting date. The growth habit and long maturity combined to make this crop less flexible in fitting into the tillage and planting system of farmers than almost any other crop or variety of crop commonly used. Many small-scale farmers have struggled with planting groundnut trials in a timely manner [ATIP RD 86-1, pp. 62-64; ATIP RD 87-1, pp. 50-51]. The crop was vulnerable to termites for which no control was recommended. Other problems that were common elsewhere, such as early and late leaf spot, and black stem rot have not as yet been serious problems.

(b). ***Farmer Incentives For Growing Groundnut.*** Assessments of household consumption needs, local markets during years with seed shortages, and marketing board prices were undertaken and the results are as follows:

i. In a study on household food consumption in the Mahalapye research villages (ATIP WP 19), groundnut was not mentioned. ATIP researchers observed that when available, groundnut was primarily used as a confectionery. Groundnut was also sometimes used in a preparation with **merogo** (cowpea spinach) and could be included in **iefata** [ATIP WP 19, p. 14], a dish with cooked sorghum or maize grain and cooked cowpea, jugo bean or groundnut grain. Generally the use of groundnut in home consumption was limited by low production. However it was noted that its use would still be somewhat low even when available. Given that groundnut was not common in the traditional diet, it appeared that the demand of most households could generally be met by production on a small plot.

ii. Several farmers growing groundnut in the Mahalapye research area began to supply local markets. A Regional Trader Survey conducted in the Central Agricultural Region in 1985 (ATIP WP 18) revealed that local trading prices for legumes, particularly groundnut and jugo bean, far exceeded BAMB prices (Table 5.2) which provided an incentive to the producer. Farmers did not sell

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[5]. Unpublished data obtained from oil seed research at DAR.

groundnut to BAMB, and only small quantities were sold to the local market.

TABLE 5.2: TRADING PRICES (PULA PER KILOGRAM) FOR GROUNDNUT AND OTHER HIGH VALUE CROPS, CENTRAL AGRICULTURAL REGION, 1985

COMMODITY	LOCAL TRADER PRICE 1985	BAMB PRICE 1985
Jugo bean	P2.25/kg	P0.37/kg
Mung/Tepary	P1.56/kg	P0.41/kg
Cowpea	P1.56/kg	P0.47/kg
Maize	P0.60/kg	P0.25/kg
Groundnut (shelled)	P2.00/kg	P0.59/kg

Source: Unpublished data.

(c). ***The Evaluation Of Labor And Crop Management Issues.*** Points to note are as follows:

i. A sole crop planting trial [ATIP RD 86-1, pp. 63-4] showed that farmers acknowledged the advantage of planting separately high value crops, including groundnut, that required particular attention [ATIP RD 86-1, pp. 63-4]. This finding was of interest for certain crops (i.e., particular varieties of cowpea). However, sole planting was already widely practiced for both groundnut and jugo bean. The need for separate management of groundnut was due to intensive labor input that was required after planting, that is for hilling, harvesting and shelling. Requirements for groundnut combined to make this and jugo bean the most labor intensive crops grown by farmers. These data were collected from low yield situations. Based on the data collected, it is assumed that harvest time per kilogram harvested will become less when yields are higher, but total harvest and shelling time could still possibly affect household decisions about groundnut production.

ii. Following on-station research which showed that hilling groundnut did not increase yield and in fact, sometimes caused two stages of maturation with either immature grain or rotted grain obtained at harvest, ATIP conducted a hilling trial to test whether this practice could be eliminated from farmer managed production [ATIP RD 88-1, pp. 37-8]. In this trial, hilling plus weeding time was recorded as 87 person-hours per hectare. Just weeding alone accounted for about 50 person-hours per hectare. Elimination of hilling saved 37 person-hours per hectare without a significant reduction in grain yield, plant stand, shelling percentage or 100 seed weight. It was concluded that hilling was not necessary.

Subsequent to the trials, farmers suggested that when the harvest was for home consumption, they would prefer to do the hilling. Farmers felt that hilling could be combined comfortably with weeding and that two stage maturity was not a problem. Immature grain could be used in the preparation of different foods. Separating mature and immature grain would require more labor at threshing, but this might not be an issue when total production was small. The elimination of hilling would still be attractive if production were slightly larger and labor became a greater issue.

(d). ***Assessment Of Methods To Improve Grain Yield.*** The major points are as follows:

i. Benefits from treating seed with fungicide have generally been significant even under farmer management [ATIP RD 87-1, II.47-48; ATIP RP, 1 p. 203; ATIP RD 85-1, pp. 7.41-7.42; ATIP RD 88-1, pp. 66-67; ATIP RD 89-1, p. 89]. Because of the low cost of fungicide treatment, this practice was very profitable. However, use of a seed treatment was not an obvious proposition for most farmers. For most crops, farmers did not treat their own seed. In the case of groundnut, farmers were forced to use any seed available because seed was not provided by the Seed Multiplication Unit and the extension service. The quality of seed for groundnut also seemed to be more important than for jugo bean or cowpea [ATIP RD 86-1, p. 62]. A baseline recommendation for using quality seed that has been treated should probably be emphasized for even the smallest-scale production.

ii. An introduced drought resistant variety (variety 55-437) was compared with variety Sellie under farmer management. The new variety was usually as good or better than the check. Farmers did not express a strong opinion about the variety. This information has been turned back to the groundnut researchers at Sebele [ATIP RD 89-1, p. 49-50; ATIP RD 89-1, p. 89].

iii. Use of row planters for groundnut production have been tested. Planters included the rotary injection planter [ATIP RD 88-1, pp. 45-46] and a unit imported from West Africa referred to as the groundnut planter, in ATIP reports [ATIP RD 89-1, p. 69]. The rotary injection planter provided a considerable seed saving over broadcast but did not give better stands or higher grain yield. These results were obtained in a very wet season. The new groundnut planter did not improve grain yield, but the planter was designed to provide the high seeding rate required for intensive groundnut production and farmers were impressed with the planter's precision. It has been suggested that this planter also be tested with crops other than groundnut, in the following seasons. ATIP researchers are convinced that intensive groundnut production will require row planting. This will improve seed saving, depth of planting, and timely planting to good soil moisture. Trial data supporting these arguments have not been obtained, in part, because most farmers are not skilled in row planting.

(e). ***Groundnut Yield Potential Under Farmer Management.*** Some major points are as follows:

i. An estimate of groundnut yield potential under farmer management, in the research villages, can be calculated from trial results obtained over the six seasons of testing (Table 5.3).

Generally, yields were very poor in dry years and from fair to good in wetter years. In these trials, farmers used traditional production practices combined with a single experimental intervention. At this level of input, these farmers clearly had difficulty with consistency. These yields were not consistent enough or high enough for many commercial needs.

ii. A more intensive package of improvements would likely be necessary to achieve a higher and more reliable yield. A groundnut package was formulated and tested with small farmers in the 1989-90 season [ATIP RD 89-2, pp. 103-4]. This package included a drought resistant variety, high

quality seed with seed treatment, elimination of hilling, row planting on good soil moisture and targeting for a population of 80 to 100,000 plants per hectare.

TABLE 5.3: AVERAGE GROUNDNUT YIELDS DURING SIX SEASONS OF ATIP RESEARCH, MAHALAPYE AND FRANCISTOWN, 1984-1990

SEASON	RAINFALL	MAHALAPYE RESEARCH YIELDS	FRANCISTOWN RESEARCH YIELDS
1984-85	200-300 mm	21 kg/ha	
1985-86	200-300 mm	49 kg/ha	
1986-87	200-300 mm	Indicated as low yields	
1987-88	>700 mm	>900 kg/ha	>300 kg/ha
1988-89	300-400 mm[a]	141 kg/ha	100 kg/ha
1989-90	420 mm[a]	153 kg/ha	

Source: See trials listed in Table 5.1.

a. Rainfall in the ATIP research villages was far below average into the month of January. This severely affected the yield potential of groundnut varieties tested which should have been planted by the middle of December.

More study is required on plant populations for different management levels in small-scale production. Station-based research proved that 80 to 100,000 plants per hectare was on the low end of an optimal range for profitable production under good management. This would require a seeding rate of 25 to 30 kg per hectare. Farmers tended to use a lower seeding rate and to achieve a still lower population [ATIP RP 1, p. 203; ATIP RD 86-1, pp. 63-64; ATIP RD 87-1, II.47-II.48; ATIP RD 89-1, p. 89]. Not only higher seeding rates, but also better than conventional land preparation would be required to consistently achieve the target population.

5.1.3.3 Recommendations. The major recommendations are:

(a). Seed treatment with fungicide and quality seed should be basic recommendations for all levels of groundnut production. This is particularly useful information for farmers or farming areas where groundnut is not a well known crop.

(b). The use of improved varieties is a useful and straightforward recommendation for farmers. At the moment, there is little of a traditional groundnut type in use, particularly following the drought of the early eighties. New varieties can be readily used by farmers when seed is made available. Seed availability is still a constraint to production for many households. The Seed Multiplication Unit and the extension service should be encouraged to expedite the production and distribution of groundnut seed to areas where interest in groundnut is indicated. The need to complete distribution before the rains begin is particularly important for groundnut.

(c). Further study should be made on the production goals of different farmers. ATIP experience would suggest that recommendations should be developed according to production goals:

i. If the goal is to produce for home consumption only, planting would be on a small plot and possibly the return to labor input would be less critical. Plant populations would be lower than generally recommended, but with a good return to seed used. Recommendations could include: good seed quality,

seed treatment, improved varieties as seed for these becomes available, and planting on good soil moisture. Hand planting could help improve timeliness and the return to seed if moisture at plowing is not good, or if seed is limiting.

ii. If the goal is surplus production, a more intensive package would be appropriate. Good early tillage and timely row planting would become more appropriate. Higher plant populations would give a better return to labor.

iii. If the goal is relatively large-scale production by the small farmer, the return to labor becomes increasingly critical as does the quality and uniformity of the grain produced. More emphasis would need to be placed on timely row planting and the elimination of hilling, and other labor saving measures that could be developed. These farmers might seek both the means to increase the yield return to labor, and a higher price incentive that is sustainable even if local production were to increase.

5.1.4 MUNG BEANS

5.1.4.1 Justification

At the request of the on-station cowpea researchers at Sebele, a Bean Baseline Survey [ATIP WP 24] was carried out in the eastern part of Botswana. The results of the survey confirmed what was already known, that beans were rarely grown by farmers. Of the farmers interviewed only 23 percent of the farmers grew any type of beans during the period 1984 to 1989. Although mung beans were specifically excluded from that survey,[6] another survey had indicated that mung beans were not widely grown even though they were known to farmers [ATIP RP 1, p. 61]. ATIP's interest in mung beans was therefore, at first, stimulated more by earlier station-based research rather than an expressed interest on the part of farmers.

Initial work with mung beans -- Phaseolus aureus -- was part of an effort to screen crops and varieties of crops for general performance under typical farmer management.

Later, mung bean was one of the crops tested with farmers under a more intensive management scheme. In this scheme, farmers planted sole plots of secondary crops rather than mixing seed and thinly dispersing the crop over the entire field. Sole planting small plots of mung beans would facilitate special management of this crop including timely harvesting. Because of its short growth cycle, the mung bean was proposed to farmers as an option for planting late in the season.

When several agronomic characteristics of the mung bean were identified as major constraints to its adoption by farmers, ATIP agronomists initiated the planting of an international variety trial[7] at the Mahalapye sub-station. Grain yield, especially in terms of harvest index, and resistance to pod shattering were key traits in the variety evaluation. Variety testing of mung bean was subsequently and correctly made the responsibility of the

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[6]. It was confined to beans other than mung beans and bambara nuts commonly called jugo beans.

[7]. A standard variety trial package from the Asian Vegetable Research and Development Center (AVRDC) of Taiwan.

oil seed researchers at Sebele.

5.1.4.2 Results And Conclusions

A list of ATIP research activities on mung bean is given in Table 5.1. Under farmer implemented planting, mung bean gave good to excellent plant establishment [ATIP RP 1, p. 203], out performing the recommended short cycle cowpea variety, ER-7. Plant growth and grain yield under dry conditions were good.

When the mung bean was placed into a completely farmer implemented management trial, many farmers were reluctant to choose to plant it. For those who did, pod dehiscence with seed loss was cited as a major problem. Mung bean production, with available varieties, required careful monitoring of maturity and timely harvesting to avoid seed loss following pod shattering. Such a demanding schedule often did not fit well into the labor allocation pattern of the household. Better resistance to pod shattering would have made mung beans more useful. Other farmers, however, also indicated that mung bean was less appreciated than the cowpea for consumption.

Even though data from the mung bean variety trial conducted at the Mahalapye research sub-station were incorporated into the mung bean commodity program, ATIP made two interesting observations. These were:

(a). There is very good potential for the mung bean to serve as a catch moisture crop. In 1984-85 and 1985-86, rainfall during the early and mid-season was very poor at Mahalapye. Mung bean plantings in February and March of these two seasons, respectively, were able to use the late season showers and produce crops of more than 500 kilograms per hectare.*

(b). None of the varieties tested showed much resistance to shattering, and all still required careful attention to the timing of the harvest.

5.1.4.3 Recommendations

Until a variety with high grain yield and good resistance to pod shattering is available, there is not likely to be much farmer interest in growing mung beans. A decision was reached in ATIP to wait until the oil seed researchers proposed new varieties for farmer testing before further work was done on-farm.

When new varieties are proposed, they should be compared with comparable short season cowpea varieties, even for late season planting.

If any mung bean variety is recommended for late season planting, planning will be required on how to provide the seed to the farming community, on a contingency basis. Better recommendations on mung bean seed storage, at the household level, would be useful in creating a year to year supply of a seed that will only be used when planting conditions are appropriate.

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*. Data are unpublished, but were handed over to the station-based groundnut researchers.

5.1.5 INTERCROPPING

5.1.5.1 Sorghum And Cowpeas

(a). ***Justification.*** Intercropping has been shown to reduce the risk of total crop failures in some countries. The rate of crop failures under the drought conditions, often

prevailing in Botswana, has been very high in recent years, for example, up to 80 percent failure of plots planted in 1983-84. Any technology which reduces the rate of crop failure should be of benefit to farmers.

Therefore objectives of the work with the commonly found sorghum/cowpea intercrop system were to examine whether:

i. A sorghum/cowpeas intercrop could reduce the risk of total crop failure relative to sole crop sorghum production.

ii. An intercrop system was actually more productive than a sole crop system under farmer field conditions.

(b). ***Results And Conclusions.*** The system was investigated in a row planted RMRI trial conducted over a three year period (Table 5.1). The intercrop system was designed as an improvement over the traditional broadcast mix cropping, but was only feasible for farmers who already practiced row planting.

Results indicated there was no yield increase in the intercrop system over sole cropping. However, it was observed that over the years some crops did better than others due to weather or environmental changes. For example, in 1986-87 cowpeas did better than sorghum due to the drought conditions, and in 1988-89 sorghum did better because aphid and rat damage to cowpeas reduced yield. This implied that an argument could possibly be made for intercropping to avoid the risk of total crop failure, especially under farmer conditions.

(c). ***Recommendations.*** The work that has been undertaken, to date, indicated that:

i. The combination of main and minor crops should be carefully selected to avoid plants competing for soil moisture and nutrients, and for farm labor.

ii. A design of a two or three row planter would ease the implementation of the intercrop system for farmers who use animal draft. This should, however, only be addressed once systems are developed, that show merit.

5.1.5.2 Sorghum And Melons

(a). ***Justification.*** A high percentage of the sorghum fields, under practical farming conditions, included the presence of melons. The impact of melon growth on sorghum yield was not known. A negative relationship would imply that it would be advantageous to sole crop sorghum and melons. On the other hand, a positive relationship would imply that the shade benefits of the melon canopy could result in reducing weed growth and soil water evaporation losses. Thus intercropping would then be beneficial.

Therefore, the objective was to assess the influence of the water melon component in the sorghum/melon mix on sorghum yield, at the plant populations used by farmers.

(b). ***Results And Conclusions.*** The FMFI systems monitoring trial implemented by 12 farmers was conducted over a two year period (Table 5.1). Participating farmers were asked to plant sole sorghum, and sorghum mixed with water melon seed, on adjacent plots using their standard single plowing broadcast system. Six kilograms of sorghum seed was planted, per hectare compared with the same seeding rate of sorghum mixed with melon seed at whatever rate the farmer chose. An impact assessment of the melon component on sorghum was made by measuring grain yield and melon cover.

No grain yield differences between the sole crop sorghum and mixed sorghum plots were observed. It is likely that at the low melon population densities used by farmers, the impact of water melon did not have an opportunity to express itself.

(c). ***Recommendations.*** Further work in this area should include:

i. The monitoring of soil moisture, which was not possible during the study.
ii. Examining the effect of increasing the proportion of melons in the mix.

5.2 LIVESTOCK ACTIVITIES

5.2.1 INTRODUCTION

The mandate of ATIP was to direct most focus on crop activities. However, recognition of the critical nature of the crop/livestock interaction in such a harsh climatic environment led to the inclusion of an animal science component in the design of the project. Overall, this input has been less than would be desirable because of limited project resources. Consequently decisions had to be made as to what general areas were to be examined. Eventually it was decided that the following two areas should receive the most attention:

(a). Topics which included a crop and livestock interaction, such as draft power, feed and manure.

(b). Small ruminants which, compared to cattle, had received little attention by the MOA, were more equitably distributed among farmers, and could provide a ready source of cash income for most families.

Because of limited project resources, these activities were carried out predominately in the Francistown area.

There was another limitation imposed on ATIP's work in the livestock arena. This was in relation to the methodological approach. It proved much easier to undertake trials at the RMRI and FMFI levels rather than at the RMFI level [ATIP RP 3, pp. 33, 97]. Put simply, the non-experimental variables were more difficult to control in livestock than in crop work because livestock were able to move and crops were not. Thus a major dimension of FSR work that was used a great deal in crop work, was largely absent in FSR work with respect to livestock. This made it difficult for FSR work with livestock to have an analogous impact to that which was possible with work on crops.

The following discussion presents research results on:

(a). Nutrition -- mineral supplementation, blood parameters, forage production and use, water and the low-lift water pump (Section 5.2.2).
(b). Draft animals -- draft power, harnesses and yokes (Section 5.2.3).
(c). Small ruminants -- disease, housing and facilities, goat milk production, estimating weight from heart girth measurements (Section 5.2.4).
(d). Chicken management (Section 5.2.5).

5.2.2 NUTRITION

5.2.2.1 Mineral Supplementation

(a). ***Justification.*** The phosphorous content in pasture in Botswana is generally low -- being relatively more acute on sandveld than on hardveld soils. The Animal Production Research Unit in DAR, not surprisingly, has determined under experiment station-based conditions, that mineral supplementation of ruminant livestock throughout the year is necessary to improve and sustain livestock productivity levels [APRU, 1990, p. 39, 44]. Phosphorous and calcium supplementation in cattle has increased growth rates of young cattle and conception rates of cows. However, perhaps because of their being browsers, average calcium and phosphorous content of goat diets have been often found above those considered to be adequate [APRU, 1990]. Calcium and phosphorous are generally supplied together. Very few farmers, in Botswana, provide mineral supplement to their animals. It was therefore considered to be desirable to ascertain whether mineral supplementation had a discernable favorable impact on animals under practical farming conditions.

(b). ***Results and Conclusions.*** Overall, the results of the studies on mineral supplementation (Table 5.4) were not very convincing. The following represents a summary of the results:

i. In general, farmers failed to understand the value or the role of mineral supplementation in relation to nutrition.

ii. Some farmers apparently expected an immediate response from feeding mineral supplements, and when this was not observed, withdrew from the program.

iii. A number of farmers remarked that the animals appeared to be in better condition, that lactating goats produced more milk, and that draft animals such as donkeys and cattle were able to work longer. However, it was not possible to verify these opinions in any objective measurable manner.

iv. An effort was made to supplement the attitudinal statements under "iii" above with a more objective evaluation in terms of blood parameters (see Section 5.2.2.2). Once again it was not possible to derive any consistent significant conclusions.

v. There were major problems in obtaining regular and reliable supplies of mineral supplements. Although bone meal was subsidized, it was often not available. A potential substitute in the form of a mineral mix was generally available, but was not subsidized and was, as a result, six times more expensive. The supply issue was further complicated because the suppliers,

TABLE 5.4 ATIP ACTIVITIES RELATING TO LIVESTOCK

MAJOR FOCUS	MORE DETAILS	YEAR[a]	AREA	SAMPLE[b]	TYPE	TRIAL	ATIP PAPERS[c]		
Mineral supplementation	Draft animals for early plowing	1984	F'Town	7,5	Trial	RMRI	PR F84-3	PR F85-3	PR F85-6
							MP 85-12	EP 86-8	PR F86-3
							RP 1, p. 195-7		
	Cattle (12), donkeys (15), goats (36)	1984	F'Town	63 herds[d]	Trial	RMRI	PR F84-5	RP 2, p. 82-7	
Blood parameters	Effect of mineral supplementation: Goats	1984-5	F'Town	1800[e]	Study	---	WP 9	WP 10	MP 88-14
							RD 2, p. 87-93		
	Donkeys	1984-5	F'Town	390[e]	Study	---	WP 8	MP 88-13	RD 2, p. 87-93
Forage	Supplemental feeding for double plowing	1984-5	F'Town	7,5	Trial	RMRI	PR F84-3	PR F85-3	PR F85-6
							MP 85-12	EP 86-8	PR F86-3
							MP 85-12	PR F86-3	EP 86-8
	Forage crops								
	Superphosphate: Crop residues plus 4 forages	1985	Both	8	Trial	RMRI	RD 86-1, p. 102-3	RD 88-1, p.17	
	Dolichos lablab, Babala millet	1986	F'Town	3	Trial	RMRI	RD 87-1, p. II.78-9		
	B005C, Dolichos lablab	1987	Mahal	23	Trial	RMRI	RD 88-2, p. 35-36	RD 89-1, p.17,24	
	B005C, Dolichos lablab	1987	F'Town	1	Trial	RMRI	RD 88-2, p. 54		
	Dolichos lablab	1988	Mahal	5	Trial	RMRI	RD 89-2, p. 49-50	PR F86-3, p.16-17	
Water	Sources	1985	F'Town	134	Survey	---	WP 3, p. 3.6-7, A 26		
	Hand lift pump	1987	F'Town	3	Trial	RMRI	PR F89-2		
Draft power[f]	Management and practices	1985	Mahal	55	Survey	---	WP 29		
		1983-4	F'Town	42,213	Survey	---	PR F84-2	WP 3,p.3.1-19	
	Arrangements and use: Arrangements	1982	Mahal	74	Survey	---	WP 16		
	Use	1983-4	Mahal	27,12	Survey	---	WP 22		
Harnesses/yokes	Farmers' opinions on donkey harnesses	1987,9	Both	4,12	Survey	---	PR F88-5	PR F90-6	
Production parameters	Statistics on typical goat herds	1986-7,9	F'Town	20,20,20	Survey	---	PR F87-2	PR F88-1	MP 86-5
								MP 86-9	MP 88-15
Disease	Clinical and Post-mortem diagnosis	1988-9	F'Town	184 cases	Study	---	WP 35		
	Serological study	1988-9	F'Town	630[g]	Study	---	WP 32		
	Internal parasites	1989	F'Town	975[g]	Study	---	WP 31		
	Lice	1989	F'Town	72 goats	Trial	RMRI	WP 26		
Housing and facilities	Sheltered kraal with feed storage capacity	1988-9	F'Town	9 kraals	Study	---	WP 27		
Milk production	Traditional	1986-7,9	F'Town	20,20,20	Study	---	PR F87-2	PR F88-1	MP 86-5
							MP 86-9	MP 88-15	WP 36
	Drylot	1989	F'Town	12 goats	Trial	RMRI	WP 37		
Chicken	Vital statistics on typical chicken flocks	1985	F'Town	213	Survey	---	WP 3, p. 3.4-5	PR F84-2	
		1985,7	Both	78	Survey	---	RP 1, p. 88-94	PR M87-2	

a. The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season and 1984-5 refers to both the 1984-85, and 1985-86 cropping seasons.

b. These refer to the number of sites or farmers. RMRI trials will usually have more than one replication at each site. Figures in the column separated by a comma indicate sample sizes in different years.

c. This can refer to a study, survey, trial or paper.

d. Breakdown according to type of livestock is given in the "More Detail Column."

e. Blood samples.

f. Many more references relating to draft power could be cited, but since topics in them are discussed in other sections, they are cited elsewhere. For example, under forage, see references to supplemental feeding for double plowing.

g. Fecal samples.

h. The survey in 1987 was informal in nature and no sample size was recorded. The 1985 survey was confined to the Mahalapye area.

the Livestock Advisory Centers (LACs) were often located a long way from farmers, transport was difficult to arrange, and supplies were only sold in 50 kilogram units.

(c). ***Recommendations.*** It is unlikely that mineral supplementation will have much impact on animals, under practical farming conditions, until general animal husbandry levels have been raised. The first step in this process is to institute farmer education programs on animal nutrition, feeds and feeding.

5.2.2.2 Blood Parameters

(a). ***Justification.*** Little was known about what constituted normal blood parameters of donkeys or goats in Botswana. This made it difficult to interpret findings from clinical material. In the past, the figures used to indicate normal blood values were those derived from Europe, South Africa and the United States.

As a result of this situation, a study was undertaken, in cooperation with the Department of Veterinary Services,[7] to determine:

i. The normal values in goat and donkey blood for the levels of calcium, phosphorus, magnesium, copper, total protein, urea, red blood cells, and white blood cells.

ii. Whether these parameters would differ in animals receiving supplementary feeding of mineral mix or drought relief cubes for goats, and mineral mix for donkeys.[8]

iii. The effects on the performance of the animal from the supplementation, as evaluated by the owner.

(b). ***Results and Conclusions.*** The major results for the blood parameter studies cited in Table 5.4, were as follows:

i. ***Goats.*** The results in Table 5.5 indicated that supplemental feeding of goats under the management conditions which existed in practical farming situations appeared to be of little value. Under the existing system, sufficient minerals were probably obtained through the browsing characteristics of goats, to sustain their productivity. A visual evaluation confirmed that both supplemented and control goats were in quite good condition.

ii. ***Donkeys.*** The results in Table 5.5 suggested that mineral supplementation was sometimes useful for working donkeys, as it appeared to increase the number of red blood cells. However, this was not likely to be economical unless the animals were anaemic to start with. Visual evaluation of both control and supplemented donkeys indicated they were in quite good condition, while the levels of blood parameters fell within the normal ranges quoted in the literature for other countries, except for copper and urea which were higher, and calcium and red blood cells which were lower.

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[7]. Recently changed to the Department of Animal Health Production.

[8]. The mineral mix consisted of equal parts of salt and dicalcium phosphate.

TABLE 5.5. LEVELS OF DIFFERENT BLOOD PARAMETERS AND INFLUENCE OF MINERAL SUPPLEMENTATION IN GOATS AND DONKEYS, FRANCISTOWN, 1984-86[a]

ELEMENT	GOATS		DONKEYS	
	OVERALL LEVEL	EFFECT SUP	OVERALL LEVEL	EFFECT SUPP
Calcium	8.91 +/- 1.61	Higher	10.07 +/- 2.11	Higher
Phosphorous	5.15 +/- 1.52	No effect	3.79 +/- 0.97	Lower
Magnesium[b]	2.59 +/- 0.71	No effect	2.07 +/- 0.65	No effect
Copper[b]	135.39 +/- 80.08	No effect	154.63 +/- 63.27	No effect
Total Protein[d]	7.83 +/- 1.36	Lower	8.02 +/- 1.16	Lower
Urea	44.42 +/- 17.32	Lower	39.38 +/- 10.65	Lower
Red Blood Cell Count[e]	11.34 +/- 2.10	Higher	8.4 +/- 1.19	Higher
White Blood Cell Count[f]	13.28 +/- 3.93	Higher	9.86 +/- 3.07	No effect

Source: See studies listed in Table 5.4

a. In the table "Overall Level" refers to the mean and the confidence limits from combining the blood samples of both the control and supplemented animals. Except where indicated, the figures are expressed in milligrams per 100 milliliters. The "Effect Supp" indicates the effect of supplementation at the P< .01 or P< 0.05 levels.

b. Since magnesium and copper were not present in the mineral mix, there was obviously no effect recorded

c. Micrograms per 100 milliliters

d. Grams per 100 milliliters

e. Millions per cubic millimeter

f. Thousands per cubic millimeter

(c). ***Recommendations.*** If additional nutritional work is undertaken in the future, it should concentrate on general nutrition, feeds and feeding methods, and educating farmers on the value of good nutrition. Until higher levels of management are introduced which improve the productivity of goats, it is difficult to make a strong case for mineral supplementation of goats under existing managerial and environmental conditions. Only a slightly stronger case can be made for mineral supplementation of working donkeys considering the prevalent managerial and environmental conditions.

5.2.2.3 Forage Production and Use Studies

(a). ***Justification.*** Intrinsically, because of the long dry season, a strong case can be made for the production of forages and storage of crop residues to feed to livestock during that period. Since 1977, APRU has looked at various fodder species including grasses, legumes and millets. A number of potentially useful species have been identified including both Dolichos lablab and babala millet [APRU, 1990, pp. 22-23].

There are, however, a number of problems associated with successfully implementing a fodder program, within the Botswana setting. Three of these are as follows:

i. There is no tradition of growing forages or preserving crop residues. Any crop residues are usually consumed in situ soon after harvest.

ii. Farmers have limited resources which generally are concentrated on producing food crops, especially as the majority of farmers are not self-sufficient in these. Therefore, it is unlikely that many resources will be devoted exclusively to producing fodder crops, especially by the poorer farmers.

iii. Even if suitable forage species can be identified, it is unlikely, given the above points, that large quantities will be produced.[11] Therefore, considering these limitations, farmers will need to make decisions about its use for the different types of livestock.

Farmers, in the ATIP areas, had expressed little interest in the supplemental feeding of livestock. However, because of the ongoing interest among MOA officials, particularly ALDEP, ATIP became involved in some work in this area. ATIP activities with respect to forage are summarized in Table 5.4. Broadly, they were classed into two groups: those relating to the potential returns from producing forage, and those relating to the identification of a suitable species for producing forage.

(b). ***Results and Conclusions.*** A brief summary of the results is as follows:

i. ***Benefits From Growing Forages.*** Poor condition of draft animals was often stated as a major reason for delays in starting arable activities at the beginning of the growing season. ATIP's interest in early plowing as part of a double plowing strategy (see Section 4.2.1) stimulated interest in supplemental feeding of draft animals at the beginning of the rainy season. However, it was difficult to draw any definitive conclusions from the work that was undertaken. This was because there were problems in determining:

-- Whether supplemental feeding was critically important in deciding whether early plowing would take place. As a result it was difficult to estimate the benefit from double plowing [ATIP FP 86/S, p. 470].

-- The cost of the forage. Although it appeared that purchasing forage was sometimes too costly in relation to the benefits, there were also major uncertainties about whether farmers themselves would produce forage with relatively high opportunity cost resources -- especially in low rainfall years when it was difficult to grow forage or food crops.

Given these uncertainties, it may well be that even if farmers were to accept the use of forage in their farming systems, it might only be situations where the benefits, in relation to the costs, are more direct and easier to establish. For example, farmers might use high opportunity cost resources for producing forage if there were a well developed market for the milk and/or fattened animals. In Botswana, there have, for example, been trials done with limited resource farmers on the winter fattening of cattle (FSSR), peri-urban dairy cattle (Dairy Unit, APRU), and milk production of goats in drylots [ATIP WP 37]. In all these cases, however, an effort was made to market a product in a reasonably short period of time and to select animals that would benefit the most from the additional nutrition.

ii. ***Identification Of Suitable Forage Species.*** In terms of work on forages and crop residues, much of it has involved responding to requests on the part of ALDEP. Species looked at, sometimes in an RMFI but usually in an FMFI format, have included:

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[11]. There is no well-established market for small-scale producers to sell forage or crop residues.

-- Crop residues: sorghum stover and cowpea haulm (mainly B005C).

-- Forage crops: mainly annuals such as Dolichos lablab and Babala millet, and to a limited degree perennials such as Buffel grass and Siratro.

Yields from the trials were variable. Yields that were obtained and measured, varied as follows:[12]

-- With 200 kilograms single superphosphate per hectare:

Dolichos lablab	1,041 to 2,212 kilograms per hectare
Babala millet	2,027 to 4,600 kilograms per hectare

-- With no fertilizer:

Dolichos lablab	651 to 1,204 kilograms per hectare
Babala millet	1,200 to 3,412 kilograms per hectare

In terms of dry matter production, it appeared that Babala millet was superior to Dolichos lablab, but in the evaluation process the percent of crude protein needs to be taken into account. In this respect Dolichos lablab appeared to be superior, ranging from 13 to 17 percent compared with 8 to 14 percent for Babala millet. A rough economic analysis of some unpublished data indicated that if the Dolichos lablab were valued at the cost of lucerne hay, the break-even yield was estimated to be about 2,070 kilograms per hectare if no superphosphate was added. It would, of course, be lower for a triple purpose cowpea such as B005C which also provides leaves and grain for human consumption.

It is interesting to note that both forage crops appeared to respond well to applications of superphosphate. However, it is unlikely that farmers would use superphosphate on forage crops in preference to food crops. Currently very little fertilizer of any sort is used by farmers. The only possible exception would be where the cost of the fertilizer is quickly translated into a cash return, for example, through the sale of milk.

Another matter of concern is the risk involved in terms of the yields of the forage crops. Two problems were associated with this:

-- Many trials failed, either because they did not germinate because conditions were too dry, or much less frequently, because of waterlogging.

-- The optimal planting time was reserved for the food crops, thus planting was seldom done at the best time[13] and weeding was usually inadequate.

(c). ***Recommendations.*** It appears that there is a great deal that needs to be done before a viable forage program is available that will be enthusiastically adopted by limited resource farmers. The following points will need to be addressed in developing a viable program:

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[12]. These figures are derived from unpublished data collected at Mahalapye.

[13]. It was usually done later.

i. Instruction on the necessity and value of animal nutrition, proper methods of utilizing feeds and techniques of feeding must be introduced to farmers before successful fodder production can occur. Once this information is understood, the concepts of fodder storage techniques and better forage crop production should be introduced. This instruction could be provided at the Rural Training Centers or by extension personnel in the villages.

ii. Research needs to continue on the use of crop residues and the identification of suitable forage species. Given the inevitable clash with the use of resources on food crop production, and the difficulty of establishing annual forage crops in dry years, when they are needed most, there appears to be merit in much greater emphasis being placed on perennials such as trees and shrubs that can form both windbreaks and living hedges. Both exotic and indigenous species need to be investigated. Issues of palatability and digestibility will need to be addressed at the same time.

iii. Once the above conditions are met, a careful assessment of farmers' interests and economic feasibility will be required. This information will provide the basis for devising suitable strategies for introducing fodder programs. Strategies for the practical and profitable use of fodder will also have to be developed, tested and demonstrated. It is likely, as suggested earlier, that the best initial entry points will be where the fodder produced can quickly be translated into a cash return.

5.2.2.4 Water And The Low Lift Hand Water Pump

(a). ***Justification.*** Watering of animals, which was usually done on a daily basis, was a very time consuming task for most farmers. Well over 30 percent of the farmers in the Tutume Agricultural District had to trek their animals for more than one kilometer to the watering source. In the same district, rivers constituted the main water source in the lands areas, and the second most important water source in the cattle post areas [ATIP WP 3, p. 3.7, A.26]. Many farmers had hand dug shallow wells at lands areas which tended to dry up during the dry season, and when in use sometimes provided contaminated water. These hand dug wells were also constructed, particularly during the dry season, in riverbeds. A well made low lift hand pump attached to a sand point could provide water in these situations which would be cleaner, and available for longer periods. Sinking a sand point would also be less work than digging a well, and pumping might take less labor than filling water troughs with buckets.

(b). ***Results and Conclusions.*** Four pitcher pumps, capable of lifting water up to six meters were imported, as were three sand points. In addition, two sand points were locally made. A summary of the results is as follows:

i. Farmer assessment was favorable, and there was a great deal of interest in obtaining similar pumps because they provided clean water, required less work than digging wells, and were easy to use.

ii. The locally manufactured sand points appeared to work as well as the imported sand points.

iii. Unfortunately the pumps were not always anchored properly with wire to a point on the bank, and consequently were lost when the river flooded.

(c). ***Recommendations***. It is recommended that:

i. Efforts should continue to determine whether the pump tested, or a similar low-cost pump, can be manufactured locally, or at least within the region. There appears to be no problem concerning the local manufacture of sand points.

ii. If it is possible to manufacture the pumps locally, then these should be subjected to extensive testing, and if successful, offered to farmers, possibly though the ALDEP program.

5.2.3 DRAFT ANIMALS

5.2.3.1 Draft Power

(a). ***Justification***. Ready access to traction is critically important in determining whether farmers can undertake timely operations, as far as arable activities are concerned. Given the resource limitations of most farmers, ownership of animal traction, either oxen or donkeys, is the only practical way in which such access can be assured. Effectiveness of the traction, once access is achieved, raises another whole set of issues. Many sections in this report indirectly address the issues of access to, and effectiveness of traction. For example, much of the agronomic work on tillage/planting attempted to make the plowing/broadcasting bottleneck less critical through developing strategies to increase the amount of water in the soil profile, and by increasing the number of days planting could be done on good soil moisture. Unfortunately most of these strategies required more rather than less draft power, therefore it was critically important to evaluate whether the additional return from that extra input was justified compared with allocating the traction in the traditional manner. Since the effectiveness of draft power is also a function of several other factors, which are considered and are summarized in Section 5.2.3.2, the discussion at this time is limited to some very general observations. A number of ATIP activities relating to this topic are referenced in Table 5.4.

(b). ***Results And Conclusions***. In 1982, animal traction, consisting of oxen and donkeys rather than tractors, was still very dominant. With the onset of the drought, two significant trends developed [ATIP WP 22; ATIP EP 88-4]:

i. The use of oxen decreased in relation to the hardier donkeys. This shift was also encouraged through the ALDEP program.

ii. Because of the drought and because of the ARAP and Drought Relief programs which subsidized the plowing operation, much greater use was made of hired traction, particularly tractors.

It is therefore not surprising that in a 1988 survey of farmers in the Mahalapye area [ATIP PR M89-2, p. 2], 51 percent were completely dependent on hiring traction for plowing purposes. This was relatively higher for female-headed households that tended to be poorer, while the hired traction was heavily dominated by tractors. Of the households using animal traction, only 23 percent used oxen, while the rest used

donkeys.[14] It is difficult to predict exactly what will happen as a result of the end of the drought and the removal of the ARAP and Drought Relief programs. However, in the absence of new plowing subsidies, it can be anticipated that:

i. As more households benefit under the ALDEP program, and re-establish their own draft capacity, the trend towards greater use of donkeys will increase.
ii. Use of hired traction, particularly tractors, will decrease, particularly with the recent removal of the plowing subsidy.

Over the years of ATIP's existence, a number of constraints in the use of animal draft power became evident. Some of the obvious ones, often mentioned and not unique to ATIP's work, are:

i. Poor management and care of animals used for purposes other than breeding.
ii. Time required for daily management of animals, such as provision of food and water, particularly at the beginning of the rainy season.
iii. Weak state of animals at the end of the dry season.
iv. Time required to catch and hitch up the animals on the limited number of days when they were to be used.
v. Poorly trained animals.
vi. Reduced slaughter value of cattle if used longer than two or three years.

It is perhaps not surprising, partly because of these problems, that opportunities for plowing and planting were missed, particularly early in the growing season. Better management of draft animals is obviously an important issue but is only likely to develop if there are perceived to be compensatory benefits (see, for example, Sections 5.2.2.3 and 5.2.3.2). The issue of water at the lands has been addressed in the current ALDEP program. In terms of the other issues it appears that donkeys, although they are operationally slower, are superior to cattle, in the sense that they withstand dry periods better and being more docile, are easier to train, and are kept longer.

(c). ***Recommendations.*** The recommendations concerning draft power are fairly obvious and need little discussion, since they are often mentioned. Three main ones are as follows:

i. To create conditions in which timeliness of operations is possible, ALDEP should continue to provide animal draft power, and water provision at the lands, at subsidized rates -- particularly with respect to donkeys.

ii. Coupled with "i" above, increased efforts are needed to develop teaching aids and procedures for instructing farmers about the handling of draft animals, management, nutrition, feeds, feeding and training.

ii. There are two strategies that are currently being considered or are being implemented to address the poor training of animals. These are:

-- Poor training is partially a function of animals being under-utilized. ATIP studies have indicated that for households owning traction, draft

[14]. In contrast, in 1982, for those households exclusively using animal traction, 43 percent of the households used cattle. Also the proportion of households relying on animals rather than hiring tractors was higher [ATIP WP 16].

animals are used much more for transport purposes than for direct arable activities [ATIP WP 22, pp. 19]. Therefore, the provision of a cart, under the ALDEP program, would probably further increase the utilization of such animals and help keep them in a more "trainable" condition.

Farming Training Courses (Section 3.3) could, and should be used as a means to provide farmers with ideas on how to train animals for specific activities, for example, row planting and mechanical weeding.

5.2.3.2 Harnesses And Yokes

(a). ***Justification.*** If the work efficiency of draft animals can be improved then it will be possible for them to increase their output per unit of time -- an important consideration in an environment where opportunities to undertake the plowing/broadcasting operation are so limited. There are a number of factors that influence the work efficiency of animals, besides the type of draft, the soil moisture and texture, etc. The other factors revolve around the capacity of the animals themselves as determined by:

i. The condition of the animals.
ii. The effectiveness with which the traction capacity of the animals is tapped and transmitted to the implements that they are pulling.
iii. The appropriateness of the design, and the existing condition and adjustment of the implements being pulled.

ATIP has addressed all of these three areas to some extent. For example, point "i" involved introducing supplemental and mineral feeding (see Section 5.2.?), while under point "iii", several types of equipment were tested (see Section 4.4.4) and condition focussed surveys have been undertaken on plows and row planters (see Section 4.4.3.1). This section concentrates on point "ii", the transmitting element.

Traditionally, harnesses for donkeys were usually made of old tire side walls wired together, or pieces of wood and rope or old ox yokes which were tied around the neck. None of these devices pulled evenly and all caused lacerations and sores from chaffing and rubbing. Consequently work efficiency was severely limited. Oxen were usually worked in pairs. The yokes were reasonably good, but the neck straps tended to choke the animals.

Work by ATIP on harnesses and yokes has complemented that of many others in Botswana. Field testing of several different types of equipment was undertaken, including Kenyan donkey harnesses and improved Sebele ox yokes. Since a great deal of work in Botswana has been done on the Sebele ox yokes, less emphasis was placed in this area.

The Kenyan harness, which is now being manufactured under the supervision of RIIC, consists of a collar which allows the donkey to exert its maximum traction capacity. The collar consists of hames (wood), pads, draft hooks, hame straps (leather), neck strap (leather), hooks and chain. The hame strap and chain make the collar adjustable. The pads -- filled with foam chips -- are fixed inside the hames and are placed against the neck in front of the shoulder.

(b). ***Results and Conclusions.*** Over the years extensive FMFI level testing of the donkey

collars has taken place (Table 5.4). In general, farmers found the donkey collars very satisfactory. Among the advantages they gave were:

i. Less time was involved in harnessing the donkeys with the new collars once they knew how to use it.
ii. The donkeys were free from sores.
iii. The donkeys were easier to control.
iv. The draft efficiency was increased, since farmers often stated that fewer animals were required to pull the plows, and less time was needed to plow a given area of land.

Overall, therefore, farmers expressed considerable satisfaction with the donkey collars or harnesses. Farmers did, however, identify a few technical problems with the collars such as the strength of the hame straps and the buckles. These problems have been taken into account in later models of the collar. Farmers also indicated that it would be beneficial if the harnesses could come in various sizes to fit any size animal.

Much less systematic work was done with the ox yokes, since farmers found the traditional ones fairly satisfactory. Ox collars, a larger edition of the donkey collar, received little interest on the part of farmers, and therefore were not tested.

Finally, in 1989, samples of the donkey collars and ox yokes were given to RHC for testing. RMRI type testing, comparing the Kenyan collars and Sebele yokes with local standard equipment available in Botswana, gave the following results [Jones, 1989]:

i.	For donkey collars:	Power capacity increased by 135 percent. Speed of operation increased by 31 percent.
ii.	For ox yokes:	Power capacity increased by 18 percent. Speed of operation increased by 12 percent.

Therefore, the enthusiasm farmers had for the donkey collars appeared to be well founded.

(c). ***Recommendations.*** Two actions that resulted from the successful testing of the donkey harnesses were:

i. The production of a four part **Agrifact** on using donkeys for draft power [Horspool and Gray, 1987].
ii. The continued local manufacture of the donkey collars under the supervision of RHC and their distribution through the ALDEP program.

There are a number of points that need to be considered in the future. These are as follows:

i. It is important to establish what price farmers would be willing to pay for the harnesses, especially in the absence of subsidies currently available under ALDEP. In the evaluation surveys undertaken to date, farmers indicated they would be willing to pay P30.00-P40.00 per collar. It is important to verify whether, in fact, this is true since a fair sized investment would be involved in fitting out a four or six donkey team.

ii. It is important to determine whether manufacturing costs can be lowered.

This needs to be negotiated between ALDEP, RHC and the local manufacturers.

iii. Monitoring of farmers' attitudes about the collars, and technical problems of the collars themselves, needs to be continued, to provide a possible avenue for introducing further improvements to the equipment.

5.2.4 SMALL RUMINANTS

5.2.4.1 Introduction

Small ruminants -- mainly goats plus a few sheep -- can be important contributors to the well-being of limited resource farmers. About 80 percent of the families own them. They provide a source of both milk and meat. However, management and utilization of small ruminants is not very systematic. There is no regular or organized marketing nor husbandry program associated with production. This somewhat relaxed attitude often extends to disposal. Consumption of goat meat is determined, in part, by the occurrence of festive occasions. Also when a goat dies, it is often consumed without regard to what caused death and whether it constitutes a human health hazard. Animals are usually only sold when there is a pressing need for cash.

ATIP has focussed a significant amount of work on issues relating to small ruminants -- particularly goats. Reasons for this have been as follows:

(a). Poorer households tended to have more goats than cattle, while cattle were much more inequitably distributed in favor of wealthier farmers.

(b). In general, programs on small ruminants with reference to research, production and marketing, had, up until the early 1980's, received little emphasis compared with those focussed on cattle.

(c). Given the right incentives and support, small ruminant production could further enhance the well-being of farmers by providing more milk and meat for domestic consumption, and with the establishment of suitable markets, through cash income from sales of milk and live animals.[15]

Typical descriptive/diagnostic work concerning goat production under practical farming conditions revealed the following situation in 1986 [ATIP PR F87-2]:

(a). The herd structure consisted of 66 percent females -- mostly young kids and does more than four years of age -- nearly 26 percent males, and about 8 percent male castrates.
(b). Average annual death loss, per flock was 11.4 percent.
(c). Average loss in weight, per goat from the wet to the dry season was 10 percent of body weight.
(d). The average kidding percentage was 137 percent.
(e) The growth rate -- that is, the average daily gain from birth to 150 days -- was 74 to 93 grams, per day.

[15] The Botswana Meat Commission (BMC), in fact, increased its purchase of small ruminants in the mid-1980's. The stimulus of BMC in developing the small livestock market at Tonota is discussed elsewhere [ATIP MP 88-10].

(f). On average farming families obtained 1.8 liters of milk, per day from 6.3 goats, with an average yield, per goat milked, of 284 milliliters per day.

Initially, ATIP studies focussed on understanding the current production environment of small ruminants under practical farming conditions, and evaluating the effect of mineral supplementation. Later efforts concentrated on identifying the causes of sickness and resulting high death losses noted as a problem in earlier studies, designing cheap but effective housing for small ruminants, and assessing the feasibility of using goats as small-scale dairy animals. Work in these areas is summarized in the following sections and in Table 5.4.

5.2.4.2 Disease

Disease problems have a severe impact on goat production. Most disease incidence does not cause death but does exert a definite influence on production. However, death losses as high as 62 percent per year have been reported indicating a very high incidence of disease. Most of these losses occur within the first year of life which would be expected. In an effort to quantify some of the causes of morbidity and mortality several studies were conducted. These were divided into the following topics:

(a) Clinical and post mortem diagnosis of disease (Section 5.2.4.3).
(b) Serological survey of diseases (Section 5.2.4.4).
(c) Internal parasites (Section 5.2.4.5)
(d) Lice (Section 5.2.4.6)

5.2.4.3 Clinical and Post-Mortem Diagnosis of Disease

(a) ***Justification.*** Death losses in goats have been reported from 9 to 62 percent per year over several years. Very little information concerning specific diseases or their incidence was available at the village level. This was due, in part, to logistical difficulties in collecting the data, and to the infrequent contact of veterinarians with goat owning farmers. This study was conducted in an effort to clarify the effects of diseases on production and to determine which diseases were responsible for the morbidity and mortality.

(b). ***Results and Conclusions.*** There were 184 cases examined. These consisted of 148 submissions of sick goats, 33 submissions of dead goats, and three submissions of histories which closely correlated with concurrent examined sick or dead goats. In these 184 cases, 40 different diagnoses were made 253 times (i.e., there were sometimes more than one diagnosis per goat). These 184 cases contained 1530 affected animals[16]. It was interesting to note that management-related diseases totalled 67 percent of the ten most common diagnoses made [ATIP WP 35, p. 3]. The percentage of occurrence of management-related diseases was as follows:

i. External parasites and diseases they transmitted: lice (15.4 percent), heartwater (10.3 percent), and ticks (7.5 percent).
ii. Malnutrition (7.2 percent)
iii. Internal parasites (4.7 percent)

[16]. A case was a presentation of diseased animals. Thus a case might have been a single goat, or a herd of goats affected with a similar problem (e.g., lice).

Infectious diseases were the second most important group. These included: caseous lymphadenitis (7.1 percent), keratoconjunctivitis (6.3 percent), contagious ecthyma (5.5 percent), and respiratory infections (4 percent), which constituted about 23 percent of the total cases examined. It is also interesting to note that, in this group, only contagious ecthyma had a prophylactic agent commercially available, and that management practices could help in reducing the incidence of all of these diseases.

All other diagnosed diseases -- 16 of them -- each represented less than two percent of the total diagnoses.

Unfortunately much of the death loss in animals was being salvaged through consumption by their owners, regardless of the cause of death. This was a dangerous practice. With increasing populations of humans and animals it is unlikely that disease incidence will decrease. Modern management and disease control will become necessary if the numbers of animals are to remain high enough to feed the population and not damage the environment. Fortunately very few zoonotic diseases were found in this study. It is likely, however, that these will increase in importance and number as human and animal populations expand.

(c). ***Recommendations.*** Suggested recommendations are as follows:

i. There is an urgent need to improve the management and nutrition of smallstock to combat management related diseases. Educational programs are required for extension staff on this issue.

ii. Control of external parasites needs to be stressed.

iii. Although control of internal parasites should not be ignored (see Section 5.2.4.5), it should not receive the same degree of priority as treatment of external parasites and nutrition management.

iv. Programs are urgently required to educate the rural population on the dangers of consuming animals killed by disease, and on the best procedures for preserving or keeping meat fresh.

5.2.4.4 Serological Survey Of Disease

(a). ***Justification.*** Unless there is some compelling reason to do so, such as a major disease outbreak, diagnostic work up and serological testing has rarely been done at the village level. This is because of the limited numbers of professional veterinary staff, most of whom have been assigned to work at the district level. It was therefore thought justifiable for AHP to devote limited resources to the serological testing of samples taken from some goats.

(b). ***Results and Conclusions.*** There was no evidence to support the presence of either brucellosis or toxoplasmosis in goats. There was an indication of some chlamydial infection in one village. However, there was no clinical evidence to support chlamydia as a cause of abortion. It was found that villagers referred to any perinatal death as an abortion, and it appeared that most of these perinatal deaths were caused by low kid birth weights from malnourished dams.

Serological evidence of bluetongue infection was very high (48 percent positive). The distribution of positive tests within the age structure was as expected, with over

75 percent in older goats and less than 15 percent in kids less than a year old. There was no clinical evidence of bluetongue virus infection observed in these herds during the research period. It is believed that the virus type or types present produce a subclinical disease, at least in goats.

(c). ***Recommendations.*** Further testing in other areas of the country would be beneficial. If an expanded battery of tests could be developed, more information could be gained from each blood sample submitted.

5.2.4.5 Internal Parasites

(a). ***Justification.*** Internal parasites are routinely assumed to be a problem in goats in developing countries. The environment in the ATIP area, consisting of low rainfall, hot weather coinciding with the rainy season, and a tendency towards sandy soils does not indicate an environment suitable for nematode propagation. Other factors which would reduce the effects of such parasites are the fact that goats, when possible, tend to browse, and that the overstocking of village grazing areas decreases the possibility of goats grazing and therefore picking up viable larvae.

Nevertheless, representative samples of faeces were collected and tests were run to see if substantial numbers of parasites did exist, when they occurred, and in what groups of goats. If deworming is necessary, it is important to know when would be the most strategic time to do so, as proper timing would be essential to the establishment of an efficient and economic control program.

(b). ***Results And Conclusions.*** A summary is as follows:

i. **Nematodes.** The mean eggs per gram (EPG) count was calculated for each of six collection periods. More eggs were found during the data collection periods corresponding to the rainy season when increased risk of parasitism was to be expected. Very little difference was found between age groups in the mean egg counts for the whole period. This was somewhat different from what was expected -- kids usually have higher counts. A possible explanation was that the area where the kids tended to feed was devoid of grass almost all year long. They fed on weeds and bush almost exclusively, reducing the potential for ingesting infective third stage larvae.

ii. **Coccidia.** Coccidia were counted simultaneously with nematode eggs. It was difficult to determine exactly what these counts meant as no clinical signs or death loss from this problem were observed during this period of time. The increased count found for kids was a predictable result. This is a common occurrence, and is expected to drop by the time the kids reach one year old. The decrease indicated an immunological response by the animal to the presence of the coccidia in its body. As long as there is no clinical evidence of disease, or no deaths occur, a count like those found should be monitored, but not treated. As with nematode eggs, higher counts were found to coincide with the rainy season, although the results may have been influenced by the fact that the proportion of kids in the goat population was higher at that time.

(c). ***Recommendations.*** The three main recommendations are as follows:

i. Since the results discussed above were derived from only one part of

Botswana and also from a small sample of goats, additional research to confirm the findings would be desirable. If they are confirmed, then the following recommendations should be implemented.

ii. It is recommended that what constitutes a disease condition in terms of levels of egg counts be reconsidered.

iii. If deworming is considered necessary, procedures need to be followed in a strategic manner taking into account the rainfall pattern and life cycle of the parasites. To gain the maximum benefits, treatment should be carried out near the end of the wet season or early in the dry season, for example, May. If a second deworming is to be done, it should be done at the end of the dry season or right at the first rain. This treatment can only be done by the farmers themselves and should be administered on a set schedule. Thus supplies of the drug[17] must be made readily available at the LAC's, and farmers need to be instructed on the procedure for its administration.

5.2.4.6 Lice

(a). ***Justification.*** Throughout the dry winter period lice infestation is severe and constitutes a possible threat to survival, especially for young kids. Anemia caused from the feeding lice, coupled with malnutrition due to the lack of forage and decreased availability of milk -- because of its primary use for human consumption -- appears to be a major cause of death for young goats. In response to this situation, a trial was conducted to test the efficiency of the drug Ivermectin[18] in controlling sucking lice and facilitating recovery from anemia.

(b). ***Results and Conclusions.*** A packed cell volume (PCV) test was used to evaluate red blood cell concentration in animals treated with Ivermectin compared with that in the control or untreated animals. The treatment was highly effective at both 28 and 56 days after treatment. "Ivomec" controlled sucking lice on goats as well as internal parasites.

(c). ***Recommendations.*** Three major recommendations, in addition to the **Promising Guideline** which has been prepared [ATIP RP 6, Section 2.4.1], are as follows:

i. Since lice infestation is a serious problem in Botswana goat herds, guidelines on the control of this parasite with "Ivomec" should be introduced, and the product made readily available to farmers.

ii. As farmers do not associate the presence of lice with any morbidity or mortality problem, farmer educational programs need to be developed on the problems caused by lice, and control programs devised that can be effectively and economically used.

iii Additional station-based research on control programs and drugs would be

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[17]. One of the drugs that can be used is the same drug used to control lice (see Section 5.2.4.6).

[18]. Sold under the trade name "Ivomec" by Merck.

amounts available for young kids.

In order for the new technology for producing goat milk to be adopted by farmers it is necessary to demonstrate that it offers considerable advantage in the production of products or cash, reduction in work load and possibly other inputs, or an acceptable combination of all three.

(b). ***Results And Conclusions.*** The major results from the traditional system and a new drylot production system (Table 5.4) can be summarized as follows:

i. ***Traditional Production System.*** Goat milk production under the traditional land extensive system was heavily influenced by the browse and grazing available. The average amount of milk produced per goat ranged from 165 to 284 milliliters per day,[19] 64 percent of the milk being retrieved in the morning. For at least part of the year, almost all farmers used the milk as fresh milk, but the surplus was soured into madila. Most madila was used at home. Only one of the farmers surveyed sold madila and these sales added considerably to his cash flow. Given the relatively low amounts of milk produced per goat under the traditionally harsh environmental conditions, kid malnutrition is likely to occur because the amount of milk produced has to be shared with human consumers. These competing demands led to the testing of a new technology concentrating on producing milk for human consumption under drylot conditions.

Although milk and meat performance indicators of the Tswana goat were not spectacular, it was recommended at the national goat meeting referred to earlier [APRU, 1987], that a breeding program be initiated on upgrading the Tswana goat. This recommendation was based on the realization that the performance of the Tswana goat is impressive given the very harsh environmental conditions that exist in Botswana. There is also considerable variability in individual performance implying that there may well be potential payoffs from embarking on a breeding program for Tswana goats adapted to the current environmental conditions.

ii. ***Drylot Milk Production.*** Using this system the environmental conditions under which the goat operates are drastically changed in that good quality feed is mainly stall fed in contrast to the extensive grazing/browsing traditional system. To reap the maximum benefit from this improved environment it was felt that goats with high milk production potential would be necessary. Therefore three types were compared under the improved management and nutrition conditions, namely Tswana, crosses and a well known milk breed. Selection of potentially suitable goats was limited by what was available. Table 5.6 compares the results from the different types of goats used. These results should be considered indicative rather than definitive in nature because, to date, only a few goats were involved and no selection was made concerning what type of goat was best suited for milk production in a drylot system.

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[19]. This does not include the amount of milk removed by the kids, which were allowed to nurse after the morning milking.

TABLE 5.6: PRODUCTION PARAMETERS FOR DRYLOT MILK PRODUCTION PER GOAT BY TYPE OF GOAT, FRANCISTOWN, 1989-90[a]

		TSWANA	SAANAN	TSWANA X BOER	SAANAN X BOER
Milk production per day (ml)		294	1,439	655	1,566
Length of lactation (days)		171	261	259	256
Milk production per lactation (liters)		50.3	375.6	169.6	400.9
Cost per liter of milk (P)					
Feed		1.16	0.22	0.43	0.17
Labor	No herding	0.39	0.04	0.14	0.12
	With herding	0.55	0.12	0.41	0.35
Total with herding		1.71	0.34	0.84	0.52

a Further details on the study, including a discussion on how the cost estimates were derived are available elsewhere [ATIP WP 37]

Given the calculated estimates of production costs, it appeared that milk production under a drylot system, of types of goats other than pure Tswana, did have considerable potential especially since the retail price of milk in the Francistown area was P1.63 per liter.

(c). ***Recommendations.*** The decision to embark on a breeding program to upgrade the Tswana goat for performing under the existing environmental conditions is fully supported. With reference to drylot milk production, further investigations are required to:

i. Determine the current and potential nutritional value of goat milk to the farming family.
ii. Select the best type of goat to be used in such a system.
iii. Test more extensively the production and economic feasibility of the system.
iv. Ascertain farmers' potential interest in adopting such a system.
v. Develop appropriate markets, strategies and regulations for selling goats' milk.

If the above issues are resolved satisfactorily in favor of drylot milk production, then successful dissemination will require farmers to be educated on a number of topics including knowledge concerning the following:

i. Goat nutrition, feeds and feeding.
ii. Sanitation and hygiene in milk production.
iii. Appropriate housing for goats.
iv. Relevant husbandry practices.
v. Fodder production and storage.

5.2.4.9 Estimating Weight From Heart Girth Measurements

(a). ***Justification.*** Scales for weighing goats are not readily available in the villages. A reasonably accurate method to estimate body weight would be beneficial in selecting animals to market either at the village butcheries or through the Botswana Meat Commission (BMC). The ability to estimate weight accurately would also be helpful in treating goats for parasites or disease, as well as a basis for selection in breeding programs.

(b). ***Results and Conclusions.*** Seven hundred and thirty-three measurements of heart girth were collected. Before using regression analysis to derive suitable equations for

estimating weights based on heart girth measurements, the data were divided into four categories:

i. Kids -- birth to three months old.
ii. Females over three months old.
iii. Males over three months old.
iv. Male castrates over three months old.

Figures have been presented in chart form relating the heart girth measurement to weight [ATIP WP 30, p. 3]. It is important to note that this technique only resulted in approximate estimates of weight and should not be used where accurate measurements are necessary (e.g., in most research).

(c). ***Recommendations.*** It is recommended that further data are collected to increase the number of observations in the estimating equation, thereby potentially improving the accuracy of the estimations. A **Promising Guideline** for more widespread testing of this technique has also been prepared [ATIP RP 6, Section 3.3.1].

5.2.5 CHICKENS

5.2.5.1 Justification

From a survey in the Tutume Agricultural District, it was found that 93 percent of the sampled households owned chickens. Most owned less than 20 [ATIP WP 3, pp. 3, 4-5]. Therefore, although chickens did not seem to be very important in the farming systems of the average household, the widespread distribution justified a small amount of survey work (Table 5.4) to obtain information on production, constraints to production, and to suggest possible areas for further study.

5.2.5.2 Results and Conclusions

Some vital statistics on typical chicken flocks that were derived from a 1985 survey in the Mahalapye area [ATIP PR M87-2] can be summarized as follows:

(a). The distribution of chicken numbers favored male-headed and wealthier households, although day-to-day tending was generally the responsibility of females.
(b). The composition of flocks was related to flock size, with rooster ownership being largely confined to larger flocks, and in general one rooster for every four hens.
(c). Hatching rates averaged 75 percent and chick mortality rate was 46 percent. Overall mortality also tended to be high.
(d). In terms of products, domestic meat consumption was considered most important followed by domestic egg consumption.
(e). Management practices appeared not to vary much by flock size. Flocks tended to range freely even at night, and were fed household scraps and residues. Health management practices were non-existent.

In 1987, an informal survey of more commercial-oriented producers as well as limited resource farmers was undertaken, to further identify constraints and to determine strategies to increase flock size and productivity through improved penning, feeding, watering and health management practices

5.2.5.3 Recommendations

It is recommended that a research strategy is developed not only for commercial producers but also for limited resource farmers who are small-scale producers. Research relevant to the latter should include low cost -- in terms of both money and time -- strategies to increase egg hatchability, reduce chick mortality, and to improve health care, as well as improve management techniques.

APPENDIX A: SPECIAL STUDIES

A1 INTRODUCTION

This appendix consists of summaries of studies and surveys undertaken that were not part of the mainstream research effort that specifically relate to the extension and policy areas.

There have been two major reasons why ATIP has given some attention to extension-related issues. These were:

(a). Under ATIP, substantial funding was directed towards the extension area in supporting a Research Extension Liaison position in the Department of Crop Production and Forestry, providing training -- in-service, short and long-term -- of extension staff, and purchasing equipment.[1]

(b). There was recognition of the significance of the research/extension linkage, and the critical nature of the role that extension staff play in bringing about agricultural development.

In contrast to the extension-related activities that mainly arose in response to what were often mutually perceived needs on the part of both research and extension staff, the policy-related activities occurred more in response to requests from ALDEP or the planners themselves in DPS.[2]

A2 EXTENSION-RELATED STUDIES

A2.1 INTRODUCTION

ATIP activities that had some relationship to extension, can be grouped into three main areas, namely:

(a). Examination of the activities and perceptions of extension staff (Section A2.2.1).
(b). Examination of the attitudes and competencies of extension staff (Section A2.2.2).
(c). Development of linkages between research and extension, and between farmers and extension.

Extension staff that were involved, were predominantly ADs. Information to address areas (a) and (b) above have primarily been through surveys (Table A.1), while activities relating to area (c) are discussed elsewhere in this report.[3]

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[1]. A report on the activities of this position is given elsewhere [ATIP RP 7].

[2]. An evaluation of the nature and content of the links between FSR teams, particularly ATIP, and extension and development/planning is given elsewhere [ATIP RP 3, pp. 53-58].

[3]. Collaboration between research and extension is discussed in ATIP RP 6 [Section 3.2.2], while farmer groups with extension staff playing a major role and research staff having a supportive action, are discussed in ATIP RP 6. [Section 3.1.1].

valuable.

5.2.4.7 *Housing and Facilities*

(a). ***Justification.*** Thorn brush kraals are effective in containing goats. However, they offer no shelter from either sun or rain and no method of storing fodder for supplemental feeding of livestock. A recommendation to design low cost shelters in an attempt to reduce the high levels of kid mortality, was proposed at a national meeting on goats in 1986 [APRU, 1987]. In response to this suggestion, ATIP undertook a study on building goat shelters. Since the initial recommendation, it became more apparent that the provision of better shelter may be only one of the strategies required to reduce mortality from management-related diseases. Although storage of crop residues and forages is not likely to develop to any great extent in the near future, it was felt that it was advisable to build a shelter that could incorporate this possibility. With respect to the fodder component, it is probably more important to keep it up off the ground to protect it from termites than for it to be covered to protect it from rain, even though rain damage will greatly decrease the feeding value of the fodder.

Improved facilities also tend to encourage better management. Better general management should have a positive effect on health and production. Less death loss and more productive animals usually lead to better utilization of the animals by their owners.

(b). ***Results and Conclusions.*** A total of nine shelter type kraals were built (Table 5.4). The design selected was large enough to hold a maximum of 54 goats allowing an average of one square meter per goat. The kraals were nine meters long by six meters wide, divided down the center lengthwise to create two pens of equal size. A shelter across the end measured three meters deep by six meters wide. A storage "loft" providing eighteen cubic meters of storage space was suggested for each shelter [see Figure 1.1, in ATIP RP 6, Section 2.4.2.2, p. 21]. Six of the constructed kraals were built with fodder storage areas. Material and labor costs varied from P88.92 to P637.37 depending on the amount of local materials and external labor used.

(c). ***Recommendations.*** Two major recommendations are as follows:

i. A **Promising Guideline** [ATIP RP 6, Section 2.4.2] has been produced for more widespread testing of the suitability of the kraal design currently being proposed.

ii. At the same time, additional investigations are required on other appropriate designs for goat kraals that are within the resource and skill levels of the farmers who will construct the kraals.

5.2.4.8 *Milk Production Studies*

(a). ***Justification.*** Goats are an important source of meat and milk. In addressing the milk production issue, initially ATIP work focussed on a diagnostic study to ascertain the traditional milk production levels and practices. Because of the apparent significance of goat milk production for domestic use in many of the poorer households, and the potential market for goat milk, attention was directed towards ways in which goat milk production could be increased without decreasing the

TABLE A.1: ATIP SURVEYS RELATING TO EXTENSION ACTIVITIES

MAJOR FOCUS	MORE DETAILS OF SURVEY	YEAR[a]	AREA	SAMPLE[b]	ATIP PAPERS
Extension staff	Factors influencing extension efficiency and crop production improvement	1983	National	213 staff	WP 1
	Subject matter competencies	1986	National	131 staff	WP 6
ADs	Activities, assessment, performance and linkages	1983	Central	52 ADs	WP 14
	Attitude towards jobs	1987	National	135 ADs	WP 23

a The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season, and 1984-5 refers to both the 1984-85 and 1985-86 cropping seasons.

b. Refers to the number of sites, farmers, etc.

A2.2 RESULTS AND DISCUSSION

A2.2.1 Activities And Perceptions

A 1983 survey of the ADs in the Central Agricultural Region [ATIP WP 14] indicated that 92 percent were male, and that extension areas encompassed two or more villages with more than 400 families. Lands areas were, on average, between six and 24 kilometers from the village where the ADs were stationed. In spite of the relatively favorable farmer to AD ratio, the farmer and extension contact often appeared to be relatively low. Factors contributing to this were often attributed to the distances involved, problems of transport, and activities that competed for time with extension, such as processing applications for farmers to participate in governmental programs, for example, ALDEP, Drought Relief, ARAP, etc. As a result, the 1983 survey indicated that, on average in the extension areas in the Central Agricultural Region, only 20 percent of the farming families were contacted, and then only once a season. Also only one in 15 farming families was contacted even once per week, and these farmers were often the same week after week. The characteristics of the farmers contacted regularly appeared to indicate they were the more progressive farmers.

In terms of perceptions, the ADs in the 1983 survey indicated that resource constraints and a lack of knowledge were the main reasons farmers did not make changes. In terms of the ten different specific technologies the ADs were questioned about, lack of a proven benefit, or other technical reasons, were only cited as major problems inhibiting adoption in the case of fertilizer use, better weed control, and early planting.[4]

Partially as a result of these and other findings, particularly with reference to the need for increasing the effectiveness of the ADs, to ensure that they worked with more farmers, and to help overcome the farmers' lack of knowledge problem, ATIP has been instrumental in developing EOFGs as a way of addressing these and other issues [see **Promising Guideline**, ATIP RP 6, Section 3.1.1].

The potential value of these groups was substantiated in other findings in the 1983 survey about the ADs' perceptions on farmers' attitudes to change. Most ADs ranked highest the statement "most farmers want to change and know of changes but lack resources." "Lack of knowledge" of changes received the second ranking, and "lack of interest" in changing received the lowest ranking.

[4]. Other technologies asked about were row planting, fencing, winter or spring plowing, use of certified seed, use of crop rotations and destumping.

A2.2.2 Attitudes And Competencies

In 1983, a different survey, this time nationwide, was undertaken involving mainly extension staff [ATIP WP 1][5] to elicit their perceptions of factors influencing extension efficiency and prospects for improved crop production. Forty-two factors were ranked. The most important factors, in order, were found to be:

(a). Improved housing for the ADs.
(b). A system for performance evaluation and promotion procedures.
(c). Ensured seed supplies.
(d). Access to motorized transport.
(e). Increased opportunities for in-service training.
(f). Increasing the proportion of practical training in extension methods at the Botswana Agricultural College (BAC).
(g). Organizing specific courses at BAC on identifying farmers' problems.

Therefore it appeared from the survey that, as far as the ADs were concerned, factors relating to their conditions of service plus their articulated needs for further training, including that relating to the extension/farmer interface, appeared to them to be of more significance in constraining their effectiveness than other factors related to improving crop production, such as those pertaining to input availability, draft power, special campaigns, research activities and research/extension communication.[6]

Another nationwide survey, this time confined to ADs and their supervisors, was undertaken in 1986 to evaluate the competency of the ADs in 102 subjects, grouped into 13 selected subject areas [ATIP WP 6]. The results indicated that the lowest perceived competencies were for farm management, inquiry methods, farm mechanization and administration. The highest areas of competency were for MOA schemes, arable crop production, and group work. With the exception of group work and work with the 4-B organization, there was a high level of agreement between the ADs and their supervisors on the competency rank order of sub-areas within the 13 subject areas. Finally, there were few differences in rank order competencies by sex, age or length of time on the job.

The survey, just discussed, was commissioned by the National Training Committee in DAFS to help identify the needs of the in-service training courses for ADs which were then started in the 1987. At the first session of this program, another survey was completed by the 135 ADs from all over the country [ATIP WP 23]. This survey sought to determine the attitudes of the ADs toward their jobs. Some major findings of the survey were:

(a). In general, the ADs were not very satisfied with their jobs, in spite of finding the work relatively exciting. Male ADs and older ADs felt slightly more positive about their jobs than female ADs and younger ADs. In terms of length of service, those of four to 11 years were the least positive about their jobs. This is a matter of concern since over 50 percent of the ADs sampled were in this group.

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[5]. Of the 213 respondents, about 60 percent were ADs, 29 percent were other extension staff, and 11 percent research staff.

[6]. It is interesting to note that the relative rankings of the different choices showed a perceptual gap between the few researchers in the survey and the ADs. Not surprisingly perhaps, the researchers tended to emphasize factors influencing the substance of the message being delivered, rather than the conditions of service and training.

(b). Correlation analysis showed a slight positive relationship between job attitude and age, indicating that job attitude tended to improve with age. There was little correlation between job attitude and sex, years in professional agriculture, and years in present position.

It was hoped that another similar survey undertaken after three years of in-service training courses, would help in creating more positive attitudes on the part of ADs concerning their jobs.

A2.2.3 RECOMMENDATIONS

There is nothing new about the following recommendations. What the results of the surveys did was to confirm concerns that had often been expressed, and to support recommendations that have often been made. Important points that need to be considered are:

(a). The proportion of female ADs needs to be increased to ensure that the needs of the many female-headed households are addressed.[7]

(b). There is a continuing need to improve the conditions of service (e.g., housing, transportation, performance evaluation criteria, and promotional opportunities) of field level extension staff.

(c). Training, including in-service, needs to be continued for field level extension staff.[8]

(d). There is a need to expand the use of Extension-Oriented Farmer Groups (EOFGs), as is currently planned in Phase II of the ALDEP program.

These recommendations, if implemented, should go a long way in helping to improve the morale and effectiveness of field level extension staff. Unfortunately, these would require a substantial commitment of resources on the part of GOB.

A3 POLICY-RELATED STUDIES

A3.1 INTRODUCTION

There are two ways to improve the agricultural potential for farm families. One is to develop improved relevant technologies, the other is to implement relevant policies and support systems. ATIP has generally concentrated on developing appropriate technologies. Over the life of the project the ATIP staff has been requested to undertake several policy-related studies, the largest being an assessment of the impact of the ARAP and Drought Relief programs in the ATIP areas. On other occasions, ATIP staff has been asked to prepare papers on agricultural policy issues for meetings or for other reasons.

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[7]. Fortmann [1985] and Bettles [1984] discuss the AD gender issue in some detail. Since this study was undertaken, this trend has, in fact, developed.

[8]. Unfortunately, the program started in July 1987 was unable to be sustained and ceased operation in 1988.

Two approaches have been used in studying policy issues:

(a). Studies have been based on relevant survey results. These surveys have either been designed to answer specific policy questions or have been surveys made for other purposes which have had a policy component, or which could be used in policy analysis.

(b). Secondary data, usually of national scope, have been used to augment data from the ATIP areas in making general policy observations based on the ATIP experience.

The reports derived from the these studies are summarized in Table A.2. Some observations and results from the studies are summarized under a number of topics as follows:

(a). General agricultural policy (Section A3.2.1).
(b). ARAP and Drought Relief (Section A3.2.2).
(c). Tractor policy (A3.2.3).
(d). Marketing (A3.2.4).
(e). Gender issues (A3.2.5).

A3.2 RESULTS AND RECOMMENDATIONS

A3.2.1 General Agricultural Policy

Major points arising out of studies and surveys relating to general agricultural policy issues were the following:

(a). General purpose programs are not likely to be successful for all technical and human environments, so programs need to be targeted to specific resource groups. For the limited resource farmer these should emphasize improvements in the traditional farming system. Food production could be increased by emphasizing technologies which are of particular use to the intermediate level farmers [ATIP WP 15].

(b). The Ministry of Agriculture could improve its delivery of technologies relevant to the limited resource farmer by improving linkages between departments, reducing ADs administrative load, and continuing FSR [ATIP WP 15].

(c). It is critically important that agricultural policies are put in place that [ATIP MP 90-1]:

i. Will encourage farmers to adopt improved technologies, since the initial changes required to move up the technological ladder are rather large.

ii. Will make production and conservation strategies complementary to each other, since individual farmers are more likely to emphasize a shorter run goal of production in order to survive, while society is also likely to have a longer-run goal of sustainability, to ensure that the ecology can also support production by future generations.

(d). There are several areas where it will be necessary to make difficult trade-off decisions [ATIP MP 88-20], including:

i. Arable versus livestock emphasis.

TABLE A.2: ATIP SURVEYS AND STUDIES RELATING TO POLICY

MAJOR FOCUS	MORE DETAILS	YEAR[a]	AREA	SAMPLE[b]	ATIP PAPERS	
General Ag. Policy	Examination of technical environment, ag. sector overview, agricultural institutions, and national planning priorities and strategies.	1988	National	ATIP and secondary data	WP 15	
	Examination of policy tradeoffs: arable versus livestock, cattle versus smallstock, tractor use, food self-sufficiency, AD's role, agricultural employment generation, commercial versus smallholder, dryland versus irrigation, commodity focus, field crops, conservation, price incentives versus subsidies.	1988	National	ATIP and secondary data	MP 88-20	
	Adoption study and need for improved technologies and policy/support systems to be complementary to each other.	1989	F'Town	158 households	WP 34	
ARAP and Drought Relief	Analysis of impact of ARAP and Drought Relief programs in areas where farming systems teams worked. Recommendations for modification of programs.	1986-7	Mahal. F'Town Ngamiland Southern	41 households 57 households	EP 88-4	RD 87-1, p.II.28-30
Traction Policy	Examination of traction use in two ATIP villages, discussion of draft power policy options and suggested priorities.	1982-7	Mahal.	> 200 farmers	WP 22	
	Participation in subsidized plowing program, demand for tractor plowing, and policy questions.	1985	F'town	29 farmers	PR F85-5	
	Estimation of tractor costs for plowing.	1989	Southern	61 farmers	EP 88-3	
Marketing	Discussion of agricultural pricing policy and its effects on production and equity.	1984	National	Secondary data	MP 84-8	
	Study of trading establishments with discussion of ways to improve agricultural inputs and commodity trade.	1985	Mahal.	163 traders	WP 18	
Gender Issues	Observations on genders issues in FSR, including household targeting, and equity within households.	1982-6	Mahal.	> 100 families	PR M87-1	
	Observations on women's arable agriculture in relation to main factors of production.	1989	Mahal.	ATIP and F'town	secondary data	MP 89-1
	Analysis of health hazards in agriculture as they affect women.	1989	National	Secondary data	MP 89-4	
	Gender issues in selected agricultural programs.	1990	National	Secondary data	MP 90-5	
Agricultural Research	Discussion of ATIP experience with various agricultural technologies, identification of technologies which could be disseminated, and areas for further research.	1987	National	ATIP data	RD 87-2	

a. The year listed is the beginning of the cropping year in question. For example, 1984 refers to the 1984-85 cropping season, and 1984-5 refers to both the 1984-85 and 1985-86 cropping seasons.

b. Refers to the number of sites, farmers, etc.

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ii. Cattle versus smallstock emphasis.
iii. Encourage or discourage tractor use.
iv. Self-sufficiency versus food security.
v. AD extension versus service.
vi. Agricultural versus non-agricultural employment generation.
vii. Commercial versus smallholder emphasis in dryland agriculture.
viii. Dryland versus irrigation versus **melapo** focus in research.
ix. Field crop versus specialty areas (dairy, horticulture, etc.).
x. Price incentives versus input subsidies.

A3.2.2 ARAP and Drought Relief

An assessment of the impact of the ARAP and Drought Relief Programs, requested by the Chief Agricultural Economist in DPS [ATIP EP 88-4], resulted in the following recommendations:

(a). The plowing subsidy should be reduced and phased out over time because it is expensive and, while it increased area plowed, has not substantially increased production. Production increases, particularly during drought periods, are more likely to result from land intensification, as a result of concentrating water, rather than increasing the areas cultivated. Because of the water constraint, subsidies should be used to encourage land use intensification through the adoption of improved technologies, particularly those that focus on getting more water into the soil profile.

(b). Seed offered to farmers should be acceptable to them and should consist primarily of millet, sorghum and cowpea varieties. Commercial channels of seed distribution should also be encouraged.

(c). The fertilizer and fodder incentives should be dropped from the programs, and weeding subsidy either increased or dropped.

(d). The row planting subsidy should be changed to a more permanent program to encourage row planting plus mechanical weeding.

(e). Destumping and fencing are more appropriately continued under ALDEP. The areas supported under the program should be limited to that which can be worked with animals. Upgrading of old fences should be included in the program.

A3.2.3 Tractor Policy

Several issues and points have arisen with respect to the increased use of tractors during ATIP's existence. Some of these are were as follows:

(a). There were several questions which an increased emphasis on tractors raised [ATIP PR F85-5]:

i. Is it a policy decision to increase tractor dependence?
ii. What are the foreign exchange implications in terms of equipment, fuel, and spares?
iii. Will tractor farmers shift from farming to doing custom-hire?
iv. Is there an infrastructure to provide spares or service tractors, or can it be

developed?

v. Will a shift to tractors create additional problems in obtaining animal drawn equipment?

vi. Does the extension service have personnel and equipment to support an increasingly tractor-oriented production system?

(b). Average total tractor costs were estimated at P36.95 per hectare when about 139 hectares were plowed per year [ATIP EP 88-3, p. 4]. However, it was concluded that, for many tractor owners, the P50.00 per hectare plowing subsidy available under the ARAP program would probably not cover the operating costs and management expenses.

(c). It was also concluded that a government tractor hire scheme would not have good prospects. A subsidy for tractor owners themselves would be preferable, providing they did custom-hire work [ATIP WP 22].

A3.2.4 Marketing

Two points with reference to the small amount of ATIP work undertaken in the marketing area were:

(a). The government is faced with many difficult choices in the marketing area, and current policies may not meet the government's agricultural objectives. Detailed research, including case studies on rural markets, documentation of price behavior, and determination of farmers' elasticity of response to changes in relative prices, etc., would help provide policy makers with the information required to make the difficult choices [ATIP MP 84-8]

(b). The existing trading system provided a relatively effective and efficient system for providing food and other consumption items to rural households [ATIP WP 18]. Possible improvements could be made by:

i. Encouraging cooperatives to provide transportation services to the nearby smaller villages.

ii. DAFS could monitor prices of inputs into agriculture and have ADs post price lists of those inputs.

iii. BAMB could be encouraged to work more through traders.

iv. Business management courses could be offered to small traders.

A3.2.5 Gender Issues

Findings and conclusions with respect to gender issues have included the following:

(a) Female headed households had less resources than male-headed households. Women worked longer hours in agriculture, but at tasks that provided a lower return than male dominated tasks. The situation was aggravated because many government agricultural programs favored male dominated activities [ATIP MP 89-1; ATIP MP 90-5].

(b) Intra-household gender equity was a major factor in determining acceptance of improved technologies. Numerous possibilities existed to improve the situation

including allocating more research and extension resources to female-dominated activities, such as post-crop establishment activities and harvesting practices [ATIP PR M87-1].

(c). Women may be at more health risk if farmers mechanize and use more agro-chemicals. Intensive education programs are needed to ensure that all farmers use improved practices safely [ATIP MP 89-4].

(d). Targeting of agricultural programs based on draft access would, in most cases, effectively address the needs of the poor and female-headed households [ATIP PR M87-1].

APPENDIX B: LIST OF PROMISING GUIDELINES

There have been a number of promising technologies and approaches arising out of work done by ATIP staff -- some in collaboration with others. In general, however, these could benefit from more extensive testing at the farm-level before being approved for publication as **Extension Bulletins** (in the case of approaches) or **Agrifacts** (in the case of technologies). Therefore, in order to provide easily understood instructions to facilitate further testing, a series of proposed leaflets called **Promising Guidelines** are presented in another report [ATIP RP 6]. Those presented in the report are listed in this appendix together with the section numbers:

(a). ***Promising Guidelines On Technologies***. The guidelines are classified under a number of themes, namely:

i. Soil Moisture Enhancement:

- Early Plowing [ATIP RP 6, Section 2.1.1].
- Contour Strip Tillage [ATIP RP 6, Section 2.1.2].
- Water Conservation Terraces [ATIP RP 6, Section 2.1.3].

ii. Planting And Weeding:

- Row Planting And Mechanical Weeding [ATIP RP 6, Section 2.2.1].
- Rotary Injection Planter [ATIP RP 6, Section 2.2.2].
- Maun Cultivator [ATIP RP 6, Section 2.2.3].

iii. Specific Crop Activities:

- Cowpeas [ATIP RP 6, Section 2.3.1].

iv. Specific Livestock Activities:

- Control Of Lice On Goats [ATIP RP 6, Section 2.4.1].
- Goat Kraal Construction [ATIP RP 6, Section 2.4.2].

(b). ***Promising Guidelines On Approaches***. These are also presented under a number of themes, namely:

i. Farmer Involvement [ATIP RP 6, Section 3.1]:

- Extension-Oriented Farmer Groups [ATIP RP 6, Section 3.1.1].
- Farmer Training Courses [ATIP RP 6, Section 3.1.2].
- Conducting Farmer Field Days [ATIP RP 6, Section 3.1.3].
- Competitions At Agricultural Shows [ATIP RP 6, Section 3.1.4].

ii. Encouraging Cooperation [ATIP RP 6, Section 3.2]:

- Cooperation Between Farming Systems Research And Station-Based Research [ATIP RP 6, Section 3.2.1]

-- Cooperation Between Research And Extension [ATIP RP 6, Section 3.2.2].

iii. Techniques [ATIP RP 6, Section 3.3]:

-- Estimating Tswana Goat Weight With A Tape Measure [ATIP RP 6, Section 3.3.1]
-- Use And Care Of The Bloodless Castrator (Burdizzo) [ATIP RP 6, Section 3.3.2].

APPENDIX C: ATIP DOCUMENTATION

C1 POLICY

Papers by ATIP staff have been written and disseminated in the following manner.

(a). ***Externally Published Papers (EP Series).*** These copies of articles and papers on ATIP work that have been externally published have been kept in limited quantities. Many of these are likely to have earlier been produced as Progress Reports, Miscellaneous Papers, etc. Likely audience: national and international.

(b). ***Research Papers (RP Series).*** These have been submitted to external review by individuals outside ATIP. This generally has meant approval by the Director of Agricultural Research and the Chief Arable Research Officer or the Chief Animal Production Research Officer. These consist of comprehensive summaries of ATIP work plus detailed reports on specific topics. Likely audience: local and international.

(c). ***Working Papers (WP Series).*** These have been papers that deserve wide circulation, and have particular methodological or empirical value. They have been submitted to internal review amongst ATIP members and sometimes external review. Likely audience: local and other people interested in farming systems work, both nationally and internationally.

(d). ***Miscellaneous Papers (MP Series).*** These have consisted of conference papers, trip reports, etc, and have not generally been subjected to review. They have been numbered with the year followed by the number in that year (e.g., ATIP MP 84-1, ATIP MP 84-2, etc.). Likely audience: mainly ATIP and other interested individuals inside and outside of Botswana.

(e). ***Progress Reports (PR Reports).*** These have primarily been papers written by staff members in ATIP, are often not reviewed, and consist of research results, methodological issues, etc. They have often been drafts of material to be published in another form. The idea has been to systematize the way in which information is produced and circulated. Each location has produced its own series. Therefore each area Mahalapye, Francistown and Gaborone has identified their papers with M, F or G, followed by the year (e.g., 84), followed by the number of the Progress Report in that year (e.g., 1, 2, etc.). An example might be ATIP PR F84-3. Circulation of the of these reports has been limited. Likely audience: ATIP staff and other interested individuals in Botswana.

(f). ***Reporting Documents (RD Series).*** These have been reporting documents required by USAID. They have consisted of annual report and semi-annual reports containing material not only on professional matters, but also covering staffing, training and administrative matters, and an work plans. Likely audience: primarily ATIP staff, USAID and MFAC, and institutions within Botswana.

C2 PAPERS WRITTEN BY ATIP

C2.1 EXTERNALLY PUBLISHED PAPERS

ATIP EP 83-1. Baker, D., E. Modiakgotla, D. Norman, J. Siebert and M. Tjirongo. "Helping the Limited Resource Farmer through the Farming Systems Approach to Research". ***Culture and Agriculture*** 19: 1-8.

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Research-Extension Liaison Office". September 1990.

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ATIP WP 1. Ramolemana, G. and A. Hobbs. "Relative Importance of Factors that Influence Extension Efficiency and Crop Production Improvement". July 1985.

ATIP WP 2. Hobbs, A. (Ed.). "Report on Farming Systems Workshop, Denman Rural Training Centre, 28th-29th June, 1983". 1983.

ATIP WP 3. Miller, W. and T. Seleka. "Agricultural Baseline Survey of Tutume District". October 1985.

ATIP WP 4. Miller, S. "Agricultural Markets for Crops, Smallstock and Animal Products in Tutume District". (Not Published).

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ATIP WP 24. Manthe, M., D. Norman, F. Worman and L. Modidi. "Bean Baseline Survey". December 1989.

ATIP WP 25. Heinrich, G., S. Masikara, S. Magaleta, and G. Moremedi. "Testing an Accelerated Extension Approach in North East District: the Case of Extension-Oriented Farmer Testing Groups". June 1990.

ATIP WP 26. Thedford, T., F. Worman, and K. Kelemogile. "Effects of Ivermectin on Packed Cell Volume of Goats when used to Treat Lice Infection". June 1990.

ATIP WP 27. Thedford, T., K. Kelemogile, F. Worman, and J. Baathodi. "Techniques and Considerations for Kraal and Shelter Construction for Smallstock". June 1990.

ATIP WP 28. "Modnakgotla, E., J. Siebert, F. Makhwaje and D. Dira. "Guidelines For Organising a Row Planting Contest at District Agricultural Shows". June 1990.

ATIP WP 29. Siebert, J., E. Modnakgotla, L. Malatsi, and A. Caplan. "Farmer Training in Row Planting and Mechanical Weeding". June 1990.

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ATIP WP 33. Norman, D., and J. Siebert. "DBase III Plus Programmes for Estimating Plant Populations and Yields from Plot Quadrat Data". June 1990.

ATIP WP 34. Worman, L., Williams, C. Ebersole and G. Heinrich. "1989 Adoption Study: Spontaneous Technology Adoption in Farmer Groups". June 1990.

ATIP WP 35. Thedford, T., F. Worman and K. Kelemogile. "Causes of Disease Among Goats in Three Villages in the Tutume Agricultural District, 1988-90". June 1990.

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ATIP WP 37. Thedford, T., K. Kelemogile and F. Worman. "Drylot Milk Production using Three Goat Types, Tutume Agricultural District". June 1990.

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C2.4 MISCELLANEOUS PAPERS

ATIP MP 83-1. Norman, D.W. "Some Problems in the Implementation of Agricultural Research Projects with a Farming Systems Perspective". Paper presented at a seminar on ***Introduction of On-Farm Research with a Farming Systems Perspective***, CIMMYT, Nairobi, Kenya, 18th-20th April, 1983. Now published, see *ATIP TP 85-1*

ATIP MP 83-2. Norman, D.W. "Helping Resource Poor Farmers: the Agricultural Technology Improvement Project, Botswana". Paper given at ***Workshop for US Technicians Preparing for***

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ATIP MP 84-7. Koch, B.A. "Animal Science Input in ATIP: Poster Presentation". Paper accompanying poster presented at the KSU Farming Systems Research Symposium on ***Farming Systems Research and Extension: Implementation and Monitoring***, 7th-10th Oct. 1984, Manhattan, Kansas, USA.

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APPENDIX E: ACRONYMS

AD	Agricultural Demonstrator
ADNP	Agricultural Development for Ngamiland Project
ALDEP	Arable Lands Development Program
ANDP	Agricultural Ngamiland Development Project
APRU	Animal Production Research Unit
ARAP	Accelerated Rainfall Arable Program
ATIP	Agricultural Technology Improvement Project
AVRDC	Asian Vegetable Research and Development Center
BAMB	Botswana Agricultural Marketing Board
BMC	Botswana Meat Commission
CFDA	Communal First Development Area
cm	Centimeter
CRSP	Collaborative Support Research Program
DAFS	Department of Agricultural Field Services
DAO	District Agricultural Office(r)
DAR	Department of Agricultural Research
DDF	District Demonstration Farm
DPS	Division of Planning and Statistics
DR	Drought Relief
DUMI	Decision Unit Management Information
EEC	European Common Community
EFSAIP	Evaluation of Farming Systems and Agricultural Implements Project
EOFG	Extension-Oriented Farmer Group
EPG	Eggs per Gram
FI	Farmer Implemented
FM	Farmer Managed
FMDU	Farm Machinery Development Unit
FMFI	Farmer Managed and Farmer Implemented
FSR	Farming Systems Research
FSSR	Farming Systems Southern Region
FSW	Farming Systems Work
GOB	Government of Botswana
ha	Hectare
HRP	Hand Row Planter
IFPP	Integrated Farming Pilot Project
IITA	International Institute for Tropical Agriculture
INTSORMIL	Sorghum and Millet Collaborative Support Research Program
kg	Kilogram
LAC	Livestock Advisory Center
LWMP	Land and Water Management Project
MDP	Malapo Development Project
MIAC	Mid-America International Agricultural Consortium
mm	Millimeter
MOA	Ministry of Agriculture
MVRU	Multiple Visit Resource Use

NCS	National Conservation Strategy
NGO	Non-Governmental Organization
P	Phosphate
PCV	Packed Cell Volume
PDR	Precision Deep-Rip
RAO	Regional Agricultural Office(r)
RELO	Research Extension Liaison Office(r)
RI	Researcher Implemented
RIIC	Rural Industries Innovation Center
RIP	Rotary Injection Planter
RM	Researcher Managed
RMFI	Researcher Managed and Farmer Implemented
RMRI	Researcher Managed and Researcher Implemented
ROFG	Research-Oriented Farmer Group
RSU	Rural Sociology Unit
SACCAR	Southern African Center for Cooperation in Agricultural Research
SMSS	Soil Management Support Services
SMU	Seed Multiplication Unit
USAID	United State Agency for International Development
USA	Unites States of America
ZN	Zinc