9.4 Some issues in planning trial work

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Before looking at the possible trial designs, five important points that should be considered when planning trials:

- ***The Need to Specify Trial Objectives***. Clearly defining trial objectives is perhaps the single most important activity in planning a trial. The trial objectives are statements explaining what the trial is supposed to achieve. Decisions regarding the trial design (i.e., the format, that is RMRI, RMFI, or FMFI, the treatments to be included, the data that must be collected, etc.) depend entirely upon the objectives of the trial. For this reason, before starting any trial activity, the researchers and other interested/involved parties must agree on the exact objectives of the trial, and these must be written down, Only after that can the trial be designed and implemented. Beginning a trial without a clear idea of its purpose and exactly what questions need to be answered can result in a lot of wasted effort.
- ***The Need to Choose an Appropriate Format to Fit Trial Objectives***. Once the trial objectives have been defined clearly, the trial design can be formulated. To decide

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

- ***The Need to Limit Research Topics to Fit Research Resources***. Researcher-managed trials (i.e., RMRI or RMFI) require a good deal of attention from senior researchers. Aside from being present during critical implementation stages, researchers must make regular field visits to each trial site throughout the season. In addition, much time is required to: plan the trials; collect the necessary inputs; and arrange for tillage, planting, weeding, spraying, and other activities, Trials also require training and supervision of the technicians and often involve a lot of discussions with farmers, Where research teams share resources -- for example, vehicles or technicians that perform work for agronomists, economists, and animal scientists at the same time -- care must also be taken to ensure that individual researchers do not monopolize the resources to the detriment of other disciplines (see Section 6.2),

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

In contrast to researcher-managed trials, FMFI trials require much less of the researchers' time during the season. Under this format, researchers are involved in planning the trials with the farmers, perhaps in collecting and supplying the necessary external inputs for the trials, and in monitoring the progress of the trials. But this is much less work per trial than is required for day-to-day management of RMFI trials. To reap the full benefit from FMFI trials, it is necessary for researchers and farmers to have frequent discussions, which can be handled efficiently through regular group meetings (see Section 9.8.6). Because farmers are providing the day-to-day management of the trials, researchers can visit the trials at their convenience, rather than having to visit at specific critical periods, This also helps researchers to spread out their work load and improve efficiency,

- ***Careful Consideration of Experimental versus Non-Experimental Variables***. The design stage produces potentially appropriate sets of improved practices for testing at the farm level, The following procedure is recommended for making decisions about the experimental and non-experimental variables in RMRI trials and, when necessary, in RMFI trials that constitute part of the testing stage:

  - The experimental variables should consist of practices for which farmers, management is flexible or of new practices that ex ante evaluation suggests would increase productivity. Flexibility in management is increased when there are under-utilized resources? whereas increasing productivity of variables is vital to breaking constraints (Section 6.4.2).
  - The feasible range of treatments for such variables is set by the flexibility that exists. For example, some flexibility could be introduced by assuming that the policy/ support system could change. Then, for example, it could be assumed that an institutional source of credit could be made available to supplement the cash flow of the farm business. The above remarks suggest that development of improved practices usually should consider the existing or definitely expected policy/support system. Therefore, results from cause-effect type research will be more relevant if researchers include in the levels of their experimental variables those that farmers might actually be able to implement. If all levels of input required are too high for the farmers to adopt, then the research may have relatively little relevance without the aid of

special support programmes for farmers. This applies not only to external inputs like improved seed or fertilizer, but also to internal inputs such as household labour availability.

- Non-experimental variables should be set at levels representative of local farm practice and/or should be implemented by farmers themselves. The failure to take into account this interaction between farmers' practices and recommendations is a neglected and crucial reason for poor adoption. For example, seed beds are often better in RMRI variety trials undertaken by breeders. Varietal testing under such conditions can provide very different results from what would occur if the seed bed preparation more nearly approximated that generally used by farmers.
- Therefore, it is important to evaluate ex ante whether the levels of the non experimental variables are likely to influence the relationships being examined between the experimental variables, Special justification should be made if the levels of the non-experimental variables differ significantly from what the farmer is likely to be able to achieve, For example, in an RMRI tillage trial, the decision might be made to keep the treatments as weed-free as possible so that they do not complicate an analysis of the differences between the tillage treatments. It is important to recognize, however, that farmers may not be able to create a weed-free environment. Therefore, it may be appropriate to record measurements of the time required in each treatment to keep the plot weed-free. Such information could be useful in later

evaluation of the appropriate tillage treatment(s) to use in trials involving farmers. In this connection, such information could be given to farmers to help in their assessment of which treatments might be appropriate.

- ***Inclusion of Control Plots***. It is important to remember that researchers and farmers need to compare treatments with something. Thus, in all types of trials, some form of control, which 'copies? the farmer's usual levels of the experimental variables, is generally used for comparison. It is amazing how often control plots are omitted (see Box 9.4).

  Many farmers might feel confident that they can evaluate new options on the basis of their experience, even when a control or reference is not physically nearby for visual comparison. This is, in fact, the situation with testing new prototype equipment (see Section 10.4.1). This approach is generally not advisable for evaluating most cropping and livestock management options. Two problems that can unknowingly arise are:

  - Bias in the thinking of the evaluators may not be recognized,
  - The evaluators (i.e., the farmers implementing the trial, visiting farmers, and researchers) may not ascertain correctly all the circumstances that surround a particular response,

  Both of these can lead readily to evaluations that are better than or worse than what would be the case if controls were included correctly.

To achieve systematic and critical assessments in FSD programmes in the farmer's own design of management strategies, it is strongly advised to conduct test options using controls and a systematic unbiased treatment of each, This latter implies use of randomization, even in the farmer's own testing.

- ***Plot Design***. Because of a number of different constraints, FSD researchers and participating farmers often have adopted the use of field-long and management-friendly plots. These plots are likely to cut across considerable amounts of variability in the field (e.g., soil, hydrology, etc.). In this case, the plot design tactic is to uniformly incorporate field variability into every plot instead of the conventional tactic of carving out portions of land that are homogeneous for making comparisons. Long, management-friendly plots first found their way into on-farm work out of necessity. Using these plots was the only way to interest many farmers and also proved the best way to incorporate farm operations in the trial in a realistic manner. It is now becoming apparent that long management plots also can provide statistical analyses equally as powerful as conventional, small, homogeneous plots (see Box 9.5).
- ***Careful Attention to Recording Appropriate Data***. Although the following discussion concentrates on trial designs, it is important to remember that implementation requires that good records and data are collected either in field books or on specially designed data collection sheets.

This data usually will be largely technically oriented in RMRI and, to a lesser extent, in RMFI trials, There are many methods for collecting such data (i.e., both input and output data) corresponding to the array of enterprises, operations, and subject area concerns, etc., that are found in farming systems around the world. Sometimes data collection procedures that would be appropriate for local FSD work can be found in local extension bulletins or research reports, Training manuals produced by the international agricultural research institutes and by NGOs and training institutions in the country where the FSD team(s) is located also can often be useful, This is because methods often need to be adjusted to fit particular situations and farming systems. For example, FSD teams helped produced guidelines for data collection in Botswana. These are available in Worman et al. 11992: pp. 149-202], Included are procedures for trial site selection, calculations of seeding and fertilizer rates, soil characterization, and so forth. Two excerpts of the Botswana work, covering measurements of plant density and grain yields, are included as Appendix A3 in this manual, They have been included because they treat the topic of measurements in mixed cropping that generally is not covered elsewhere, while at the same time illustrating the need to make adjustments in the data collection procedure to fit the environment in which the research is being undertaken.

An important component of this data collection -- and, unfortunately, it is something that often is omitted -- is recording of data that describes the environment under which the trial was undertaken, These site descripters include data on soil type, weather (i.e., temperature and rainfall), unusual features, etc., which help in ascertaining the potential for extrapolation to other areas.

However, it is important particularly in RMFI and FMFI trials, that such data be supplemented by socio-economic information. If this is not done, and often it is not done satisfactorily, the trials are really simply technically oriented, multilocational-type trials and the major objective behind involving the farmer -- that is assessment of relevancy under practical farming conditions -- is lost. With reference to socioeconomic type data, attitudinal or more qualitative-type data can be very useful, Because of costs, however, care must be taken in deciding what objective or quantitative types of data need to be collected (see Section 6.5.1). Usually such types of data relate to physical data (i.e.' usually technical data already collected); labour and equipment requirements by type and operation; and price data relating to inputs, outputs, and wages [Worman et al, 1992: pp. 187-193, 200-201]. Collection of such date can be particularly time consuming. Therefore, sometimes it is possible to use standard labour coefficients for some operations that don't change between operations and only collect labour data on operations that are likely to be affected by the operation. In other cases, it is appropriate to collect socio-economic data on only a subset of all trial sites.

- ***Decision Concerning Evaluation Procedure***. In order to ensure an appropriate experimental design and data collection procedure, the evaluation procedure should be decided on before the trial is implemented.

BOX 9.4: FARMERS CAN BE RELUCTANT TO HAVE CONTROL PLOTS

The use of controls or check plots is important to researchers in providing standards against which experimental treatments can be compared. A recent survey of farmers in Kansas, USA, concerning their attitudes about on-farm research [Freyenberger et al, 19941, which incidentally were very positive, indicated that farmers tended not to be very concerned about controls, perhaps because of familiarity with their own farm and the fact that they felt it was necessary only to convince themselves of the value of the results. Only 36% of the farmers implementing their own on-farm research had controls likely to be acceptable to researchers, with those farmers particularly interested in sustainable agriculture practices being the least supportive of this strategy (i.e., only 28%). In fact, 25% of all the farmers and 35% of the 'sustainable agriculture' farmers used only a before- and-after comparison.

The implication of these findings is that compromises will be needed on both sides, if effective, collaborative, working relationships are going to develop between farmers and FSD researchers and if farmers are to be able to provide an effective means for other (i.e., visiting) farmers to compare the proposed change with what is currently done. This latter point is particularly important, because the survey also revealed that farmer-to-farmer communication and interaction were very important sources of information on possible changes.

BOX 9.5 LONG NARROW PLOTS MAKE GOOD PRACTICAL AND STATISTICAL SENSE

Farmers participating in an on-farm research programme in the state of Iowa, USA (i.e., Practical Farmers of lowa, PFI) opted for narrow plots that ran the entire length of the field. Usually, the width of these plots was about two widths of the widest piece of equipment used, Farmers found that using this plot design enabled them to make side-by-side comparisons of a number of treatments and even to randomize treatments much more easily than they could using small 'garden plots, typical of most research work.

These management-friendly plots not only improved the quality of implementation of on-farm trials, they also boosted their statistical power [Thompson and Thompson, 1990], Statistical power, as shown by low percent coefficients of variation (CVs), was found to be actually greater for on-farm trials with long plots that cut across large amounts of field variability than for shorter on-farm plots or for small station-plots.

For measurements on corn, soybean, and wheat yields in a range of experiments, CVs ranged from:

- 0.7-5,9% for plots 6m wide by 365m in length in which the entire plot was planted and harvested by the farmer.
- 4.5-15.2% for 12m by 38m plots managed by researchers but conducted on farms,

- 8-15% for small station-plots that were planted and harvested by hired help,

A related study showed that costs and information returns for farmer managed research was superior to those of station-based research in these subject areas.

This implies that FSD personnel should not conclude that on-farm work, though relevant, is always technically inferior to station managed research,

9.5 Trial designs appropriate to crop research

A number of possible trial designs can be used in FSD work, especially for those relating to crop research. For convenience in presentation, they can be divided into two major groups as follows:

- Those that involve replication of treatments within fields. These are most suitable for RMRI trials, whereas the simpler designs can be used in RMFI trials.
- Those that usually have no replication of treatments within fields. These very simple designs are used in FMFI trials.

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

9.5.1 Trial Designs Involving Replication within Fields

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

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

  This type of design is appropriate only for experiments where plots cannot be grouped meaningfully. An example would be where all plots are on the same soil type, the soil is of equal depth in all plots, and the field has very little or no slope. The CRD is the simplest design in terms of the analysis of the data, especially if some treatments are lost. Less information is lost with missing data in the CRD than with other designs. The disadvantage of the CRD is that it is not very precise, because all of the variation between experimental units is included in the experimental error term,

- **The Randomized Complete Block Design (RCBD)**. The RCBD is used where experimental units -- that is, plots in field trials -- can be grouped meaningfully. For example, plots higher up a slope may be grouped together, and plots lower down the slope may be grouped together. Or, if soil depth varies from one end of an experimental area to the other, plots on the end with shallower soil may be grouped together, and plots on the end with deeper soils may be grouped together, These 'groups' generally are referred to as 'blocks', In the RCBD, because each block contains a complete set of treatments, these blocks also can be called replications or 'reps' for short, The reason for grouping the treatments this way is so that differences observed between treatments are more likely to be due to the treatments themselves, rather than the differences between experimental units,

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

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

  Split plot designs are used commonly when:

  - Large experimental areas are required for one treatment but not for others (e.g., irrigation treatments on different crop varieties).
  - Researchers wish to include an additional factor in an experiment to increase the scope of the experiment (e.g., adding a fertilizer treatment to a trial involving several tillage treatments).

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

  A split plot experiment is often a convenient approach for implementing research that involves the comparison of different levels of two or more factors. However, the designs and the analytic procedures are slightly more complicated than the CRD or RCBD.

In RMRI type trials, any of the above designs can be used satisfactorily in on-farm trials. However, in the case of RMFI trials, it is probably best to restrict trial designs to an RCBD or CRD, to restrict replications to two or a maximum of three per farm, and to restrict treatments to a maximum of four or five. Remember, the more complicated the trial is, the more difficult it will be to obtain 'qualitative' farmer assessment of the different treatments. The idea of seeking farmer assessment as early as possible in the research process, as argued earlier (Section 9,2), can be important to avoid wasting research resources and time on developing technologies that will never be, or are unlikely to be, acceptable to farmers.

9.5.2 Trial Designs Usually Not Replicated within Fields

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

- ***Paired Comparisons***. Using this approach, farmers implement a planned comparison in their field on previously marked plots. This approach generally is used for simple comparisons, for example, with and without fertilizer, row planting versus broadcast planting, or single ploughing versus double ploughing. However, it also can be used to test an '***improved***' system against the farmer's ***'traditional***' system, for example, a system involving double ploughing, row planting, and phosphate fertilizer versus the traditional broadcast planting, single ploughing, unfertilized system. This format generally requires that the same crop and variety be used for all paired comparisons, with the same seeding rate across trials and farms, and the same planting date for each plot in a pair. Then, aside from treatment variables, the management of the comparison follows the farmer's usual practices.

The number of treatments in each set of comparisons also can be expanded where it is necessary and appropriate. For example, the approach could be used for crop variety trials, where researchers wish to determine the best variety of a crop to recommend within a region. In this case, the comparison might include three or four new varieties, to be compared against the farmer's own.

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

- It is fairly simple to understand and implement.
- It generally does not require much of the farmer's time or management,

because it is a small trial.
- The results are fairly clear and easy for farmers to interpret -- whether or not there has been any benefit from the 'improved' treatment.

The format is also easy for researchers to apply over a large number of fields. Once the sites have been selected and marked prior to the start of the season, farmers can usually implement the treatments themselves, with researchers checking the progress in the regular group meetings and/or visiting the fields at their convenience (Box 9.6).

As indicated, these types of trials usually are best replicated across a number of farms, rather than being replicated within a farm, However, this observation is based on experiences in low-income countries with limited-resource farmers. Limited farmer resources in terms of labour, traction, land, etc., often make it difficult for a farmer to handle more than one replication adequately, especially because plot sizes used tend to be larger than would generally be the case in RMRI trials. Nevertheless in high-income countries replication within a field becomes a more realistic possibility, although as will be seen later (see Section 10,4,3), there are advantages to involving more farmers and testing under as wide a range of environments as possible, Therefore, replication within farms should not be undertaken at the expense of involving more farmers,

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

    - Observing its operation in the field.
    - Holding informal discussions with the farmers who use it,
    - Conducting a formal survey of the farmers who use it.

  A formal survey may be used to obtain quantifiable data on farmers' opinions, the problems they encounter in using the equipment, their suggestions for improvements, and their judgments as to whether or not the equipment could benefit their farm operations (Box 9.7),

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

- ***Superimposed Trials***. As indicated earlier (see Section 9.2), superimposed trials can be used to test relatively simple innovations under farmer management. In these trials, a treatment is superimposed in a plot or plots on a farmer's field, often after the farmer has started the initial crop husbandry work, usually after planting. The comparison in this case is generally between the farmers own system and that system plus an additional treatment, for example, an extra weeding or a top dressing of nitrogen, etc. The treatment plot yields are compared with yields from an equal area of the field adjacent to the treatment plot. There may be more than one comparison per field, and comparisons usually are made in a number of fields.

Unlike the other types of trials, discussed earlier, which are implemented according to a plan drawn up at an earlier date, superimposed trials can be pre-planned or unplanned in the sense of responding to a problem that has arisen and for which a satisfactory solution is sought. Examples of the flexibility of superimposed trials are given in Box 9.8 .

BOX 9.6: FARMER GROUPS ARE SUITABLE FOR MONITORING FMFI TRIALS

Farmer groups (see Section 9.8.6) have many good characteristics, one being to provide a forum for making the use of researchers' time more efficient, particularly with reference to FMFI trials that they need to visit only irregularly. In one area of Botswana, when a set of this type of trials was managed through group meetings, farmers about 100 comparisons were properly implemented in both the 198788 and 1988-89 seasons.

BOX 9.7: TESTING EQUIPMENT REQUIRES A DIFFERENT APPROACH

A new type of donkey collar was introduced in one area of Botswana. Originally, it was designed and manufactured in Kenya where it was in general use. It Botswana, it was tested by several farmers. Both informal discussion and survey data showed that it was an improvement over the equipment farmers had been using up to that time. After that study, local production of the collar was started and collars were offered as part of a development extension programme.

BOX 9.8: SUPERIMPOSED TRIALS PROVIDE FLEXIBILITY FOR RESEARCHERS

Two examples from Southern Africa illustrate the flexibility of superimposed trials:

- ***Pre-Planned***. Experiment station trials had determined earlier the ideal plant populations for sorghum and millet. However, in FSD work, it was found that few farmers achieved the ideal plant population, Therefore, the cooperation of a few farmers who already had standing crops was obtained, in order to investigate the practicality of gap filling -- through transplanting -- and thinning, so that farmers could more closely approach the optimum plant population.
- ***Unplanned***. A farmer with a plot infected with many weeds was not keen on investing a lot of labour in weeding. In order to demonstrate the benefits of weeding on the eventual yield of the crop, it was suggested that he weed only part of the plot.

Advantages of superimposed trials include the following:

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

Thus, there is considerable potential for superimposed trials to respond to unanticipated opportunities and as tools in convincing farmers to change their strategies.

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9.6 Approaches to livestock trials

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Animals are complex biological systems involving many elements such as health, nutrition, genetics, reproduction, and behaviour. The multiple uses of animals and the multiple ways they interact with other components of the farming system all make trial work with animals very complicated compared with crop research. Table 9.2 shows some of the differences between crops and livestock that have important implications for research related to livestock. Some of the implications for handling these are given in Table 9.3 together with suggested strategies and techniques for handling them in on-farm testing.

TABLE 9.2: COMPARISON OF CHARACTERISTICS OF CROPS AND ANIMALS

CHARACTERISTICS	**CROPS**	**ANIMALS**
Mobility	Stationary	Mobile
Live cycle duration	Generally less than six months	Generally more than one year
Life cycle synchronization	All units synchronized	Units seldom synchronized
Multiple outputs	Only grain/tuber and residue	Many: meat, hides, milk, manure, power
Non-market inputs/outputs	Fewer	More
Experimental unit size	Small, divisible	Large, indivisible
Producer attitudes	Impersonal	Personal, taboos

Management variability	Less over shorter period	Greater over longer period
Observation unit numbers	Many	Few
Variability of observations	Lower	Higher

Source: Amir and Knipscheer [1989: p. 13].

Obviously, in designing and testing research work involving livestock, these characteristics and issues need careful consideration. In general, on-farm trial work with livestock has been much more difficult to implement and less successful than that involving crops. Therefore, it is inevitable that greater emphasis tends to be placed on RMRI type trials -- often on experiment stations -- than should be the case in crop research. There is also another important reason for this tendency. These trials involve more of a risk for the farmer than do crop trials, because they affect the limited number of livestock owned by the farming family and such trials generally take place over a longer period of time. To minimize farmer risk, it is most important that basic research affecting a trial be completed on-station before the trial is moved to the farm.

TABLE 9.3: SOME CHARACTERISTICS OF LIVESTOCK AND THEIR IMPLICATIONS AND STRATEGIES FOR ON-FARM TESTING

CHARACTERISTICS	IMPLICATIONS	STRATEGIES AND TECHNIQUES
Mobility	Difficult to measure and control non-experimental	Subjective evaluation (eye balling) by farmer, researcher, trader, or buyer.
		Interviewing persons keeping, owning, or
		monitoring animals.
	Variables	Ear tagging or using some other means of identification.
		Moving feed to animals.
Life cycle duration	Increases costs and likelihood of	Recall surveys among farmers.
		Simulation modelling.
	Losing experimental units	Combination of cross-sectional and longitudinal analysis.
Life cycle synchronization	Difficult to find	Total live weight per farm.
	Comparable units	Production indices (kilograms weight produced/kilogram weight maintained).

		Internal indices (parturition interval, lactation period).
		Adjusting milk production to account for calving date variability.
Multiple outputs	Difficult to measure and value treatment effect	List outputs and alternative trade- offs.
		Determine value by: level of management, market, or farmers, own assessment based on interviews.
Non-market input/outputs	Difficult to value input/output	Labour: opportunity costs.
		Survey of labourers', measuring skills.
		Measuring forage intake with two measurements: before and after.
		Surveying farmers for determination of value.
		Valuing manure as an example:
		NPK value (chemical fertilizers used);
		(Market) value of tethering animals;

		Fuel equivalent value;
		Measurement of crop yield increment due to manure
Experiment unit size	Increases cost, risk to cooperator	Work with groups of farmers rather than individual farmers.
		Introduce risk insurance provision.
		Use proxy measurements, such as heart girth, instead of weighing.
Producer attitudes	Difficult to cull, castrate, ear mark	Need to be identified initially but difficult to quantify.
Management variability	Difficult to isolate treatment effect	Comparing two treatments on same farm (difficult because of lack of enough animals and cumbersome for farmer).
		Comparing before/after treatment by same farmer.
		Compare two or more farmers (requires several farms and is more costly).
Observation units	Large statistical	See strategies under management

	variability	variability.
		Quantify normal death loss when developing test.
		Experimental design must allow for loss of experimental unit.
Ownership determinaion	Joint management	Outputs: see above strategy on multiple outputs.
		Determine decision making process. Inputs: commercial land/pasture.

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

In recent years, there has been increasing concern with evaluating the appropriate roles for station-based and farm-based research with respect to livestock, For example, participants at one conference concluded that [FSSP, 1986: pp. 5-71:

> **"On-station research should focus on testing higher yielding variants of old enterprises (e.g., from other areas) or testing new enterprises as suggested by ex ante analysis, and by on-farm research. Because this kind of research (introducing new enterprises or improving old ones) has to be more controlled than on-farm research, it should be done on-station before on-farm research, unless the**

technology is well established and unless there are reasonable grounds to believe that on-station research can be omitted."

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

- **To give an *ex ante* description of the production systems and to identify relevant problems for on-station research.**
- **To verify on-station results,**
- **To provide a continuing flow of information to on-station programmes.**
- **To test new technologies under farmers' conditions.**
- **To demonstrate improved technologies to farmers and extension personnel.**

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

- **Compared to crop trials, more frequent monitoring is required for livestock trials, which increases travel costs for on-farm research.**
- **Because animals do not care for themselves and do not stay in one place like plants, the results are likely to be less accurate on-farm, compared to the more controlled environment of the station,**
- **In working with livestock, laboratory facilities may be more important than in working with plants. This is because fewer animals are involved, and the loss of an animal is a**

major event,

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

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

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

In addition, if the researchers are going to conduct research either by providing animals to

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

9.7 Testing within crop-livestock systems

In low income countries, the vast majority of farmers who keep livestock also grow crops. Therefore, any proposed changes in technologies relating to livestock have to be evaluated in terms of their potential impact on the whole farming system. Thus, testing on-farm can be a very important exercise. Testing of technology alternatives, within the crop-livestock system, may be carried out on a single management component component technology research -- or on a combination of technologies that may involve both crop and animal production techniques. Thus, the objectives of the testing phase include:

- **Measuring the performance of alternative technologies in the farm environment.**
- **Comparing alternative component technologies and production systems with those**

currently used by farmers in terms of biological productivity, farm resource use efficiencies, and farmers' preference.

- **Identifying labour, cash, and agricultural input requirements of alternative technologies.**
- **Identifying resource conflicts at the farm or community level that may be caused by the alternative technologies.**

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

Therefore, as with crops, it is important for farmers to be involved as much as possible in trials involving livestock. Some ways that farmers can be involved in livestock trials are:

- **As an observer, where the researcher designs and executes an RMRI trial on the research station or on the farmer's land sometimes with her/his animals, These test animals often are used through a rental agreement, However, as has been argued earlier with respect to crop research (see Section 9,2), there is considerable merit in exposing farmers to such work and eliciting their opinions on the proposed treatments and the results.**

- **As implementor of a test with the farmer conducting all operations (RMFI) using his/her resources and animals, often augmented by production inputs or implements and with supervision from the researcher, However, experience has indicated that RMFI trials with respect to livestock are generally not very successful, meaning relatively greater emphasis on RMRI type trials, This is because ceteris paribus conditions tend to be much more difficult to maintain with on-farm livestock trials than with those relating to crops (Box 9.9).**
- **Through the farmer testing the technology at the FMFI level with or without a support system providing the requisites for the technology to be implemented.**

BOX 9.9: LIVESTOCK MOBILITY MAKES RMFI TRIALS DIFFICULT

In Botswana, recommendations exist for mineral supplementation of cattle and small ruminants. However, RMFI trials that one FSD team was involved in with respect to mineral supplementation failed to demonstrate convincing results. One of the reasons was undoubtedly the fact that livestock in the harsh environment of Botswana tend to be very mobile and, as a result, do a substantial amount of browsing, which provides a variety of minerals. Browsing was not considered an option when testing the benefits of mineral supplementation in experimentation in on-station RMRI trials.

Therefore perhaps, given the current livestock practices in Botswana, mineral supplementation is not a relevant recommendation, However, the experience also highlights

the need to take current farming practices into account when designing proposed improved technologies.

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9.8 Implementation of trials with farmer involvement

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9.8.1 Regular Farm Visits

It has been said that the best 'fertilizer' a farmer can apply to the crop is foot prints in the field. In other words, regular field visits are extremely important for ensuring a good crop or a productive animal. The same applies to good trials.

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

- **Only through regular visits will researchers understand what has happened in the trial throughout the season and be able to correctly interpret the results,**
- **Only through these visits can the researchers observe and guide the performance of the technicians and farmers -- in the case of researcher-managed trials -- and be sure that the trials are implemented properly and the data are collected properly.**
- **For trials with researcher management, it is particularly important that researchers are present when treatments are being applied and critical events occur in the implementation of trials (e.g., when crops from trials are harvested). Mistakes during such activities could greatly affect trial results and lead to either misinformation being produced or the loss of valid results from a trial.**
- **Lastly, in researcher-managed trials, only through regular field visits can researchers identity problems in a timely manner (e.g., developing weed infestations, developing insect problems, or disease problems in livestock) and deal with them appropriately.**

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

9.8.2 Interacting with Farmers

Interactions between research and extension personnel and farmers sometimes can be poor

because of shyness, a lack of respect, or not knowing how to communicate with the farmers In order to improve the quality of such interaction, it is important for FSD and extension staff to accept the following:

- **Researchers should realize that they are there to serve the farmers, not the other way around**
- **Researchers must understand that the farmers are not there only to do trials and demonstrations. They have other more important objectives, like working to teed their families. Therefore, farmers cannot always give high priority to trials and/or demonstrations. Therefore, it is important to be reasonable about the level of cooperation and collaboration requested of the farmer. For example, efforts should be made to avoid becoming over-committed and putting him/her into a high risk situation.**
- **Efforts should be made to ensure that both farmers and researchers know exactly what the agreement is. In other words, a type of contract -- which may simply be verbal in nature -- needs to be agreed upon. Also, care should be taken by FSD team members to deliver on any promises of help that they make and to be very wary about building any reward systems into the contract terms. In general, reward or insurance terms, such as guaranteeing a certain level of return, should be avoided, particularly in trials at the FMFI level,**
- **Sometimes FSD and extension staff feel they must give answers to all questions, whether they are sure of their facts or not. Instead, they should realize that giving wrong information to farmers is much worse than saying 'I don't know', because**

eventually they will lose the farmer's confidence. In this case, it is best to answer: 'I don't know, but I will find out', Researchers also can check with other farmers to see if they have any good solutions.

- **The concept of the trial and the procedures to be used must be explained fully and carefully, several times, especially where farmers are conducting experiments for the first time, because they sometimes have difficulty understanding the concept of 'comparisons,, Any disappointments that result from farmers not collaborating to the degree anticipated should be transmitted to the farmers in a constructive rather than a destructive manner. It is important to try and learn from such experiences and plan in the future, if possible, to make changes that will avoid these happening again,**
- **Because no technology works in all places, at all times, it is dangerous to tell farmers 'this works', 'this doesn't work,. Instead it is better to say, 'in our experience, this works more often than that', then suggest the farmers try it and form their own opinions,**
- **It is also important to be well prepared, Farmers lose confidence when they come to a demonstration and the equipment doesn't work, or they are promised seed and it is not delivered. FSD workers should prepare thoroughly, in advance, before meeting farmers and work hard to fulfill their promises.**
- **It is important to listen to and, where possible, desirable, or relevant, attend to farmers' problems quickly.**

Farmers, participation is critically important in FSD. The level and degree of participation of

course varies according to the nature of the trial. In RMRI trials, the farmer provides the land and the researcher provides all the inputs and controls the trial. The farmers' contribution is in a sense minimal. On the other hand, in RMFI trials, the farmers' participation is much greater, because they are responsible for implementing the trial under the management of the researcher. Thus, in this type of trial, the quality of the interaction becomes critically important. Finally, in FMFI trials, the farmer is in complete charge and the researcher is dependent on good interaction in order to reap any benefits from the trials.

Although the intensity of interaction with the farmer will depend on the type of trial, a number of factors will influence the nature of the relationship. These are discussed below for each type of trial. Researcher-farmer relations, location of trials on the farm, on-farm trial designs, field data management, and standardization are a few things that need to be considered when conducting research in farmers, fields with their active participation. Although the tone of the following discussion implies emphasis on on-farm trials involving crops, many of the principles apply to on-farm livestock trials as well.

BOX 9.10: RMRI PLOT SIZES ARE DETERMINED BY ENVIRONMENT AND TOPIC

In semi-arid Botswana, the size of RMRI plots has generally been a minimum of 6m by 20m when less precise methods of planting and spreading fertilizer have been among the included treatments. These plot sizes could be smaller if more precise placement methods were used.

For soil moisture conservation/tillage trials using animal draught, plot sizes of 40m to 50m in length and 10m to 15m wide have been satisfactory. Using tractors in such trials might require plots up to 0.5 hectares in size. For these types of trials, large plots are necessary to ensure that treatment effects are separated within the experiment. the researcher's supervision? members of the host family can participate when invited or when they have time and are interested in learning more about the technology. The farmer also can be hired to do some of the work, for example, weeding, bird scaring, or threshing, and may provide the draught power. The farmer is paid for this work, and in most cases, the grain yields are given to the farmer in lieu of rent.

9.8.3 Implementation of RMRI Trials

Relevant points with reference to RMRI trials are as follows:

- ***Selection of Farmers*. In this type of trial, the selection of farmers depends less on their resources -- because these are provided by research -- and more on the technical environment (e.g., are soils representative for the area?), Nevertheless, significant secondary criteria in the selection process are the interest and potential for cooperation individual farmers have shown, Also, they need to possess a large enough area of suitable land to allocate to a replicated trial. Each farmer is approached individually. Researchers meet the farmer before the planting season to discuss the proposed trial and to find out if the farmer is willing to host a trial. The farmer is**

encouraged to take an interest in the implementation of the trial and, to the extent possible, to comment on and evaluate both the proposed treatments and the results. The more the farmer understands about what is going-on, the more capable he/she will be in explaining it to visitors and friends, so that more individuals can learn from the trial.

- ***Site Selection*. The site should be representative of the target environment and should include the type of soil, topography, etc. suitable for research work. It is important to make clear to the farmer that such conditions are needed to prevent bias in the results. A trial site should not be located where there are paths, ditches, large trees and other conditions that are not normally part of the environment. To ensure good researcher-farmer relations, it is very important that the site be satisfactory for both the farmer and the researcher. Plot sizes obviously are determined by the content of the trial and usually can be the same as used on-station (Box 9.10).**
- ***Implementation.* Farmers must understand the importance of the trial to the researchers. The risk of not completing trials is higher on farms than on experimental stations. All the arrangements and the implementation are carried out by the researcher, but the farmer, as a partner, should be informed of the whole procedure so that he/she will not destroy it through independent action or by accident. Although all the work is carried out by the researcher or under**
- ***Data Collection*. Less information usually is recorded in on-farm trials than in trials conducted on experiment stations, Researchers should not collect data beyond what is appropriate for the area and the trial, Farmers develop high expectations when**

something is done on their farms, and their curiosity should be satisfied as quickly as possible if their support and assistance are to continue, Consequently, it is important to ensure that as little time as possible lapses between the completion of trials (i.e., recording data) and informing the farmer of the results,

- ***Yield Estimation and Result Assessment*. For most trials, the final stage is assessing and evaluating a given technology, with yields from the different plots representing the differences between treatments, A suggested procedure is as follows:**

    - **It is important to inform the farmers that production obtained from the trial will eventually be theirs to keep. One approach is to leave all the grain at the farmer's house for drying, threshing, and weighing. However, sometimes this is not possible if detailed information is required on seed weight, seed number. etc.**
    - **Farmers should be given the opportunity to see the yield differences that occurred between the plots before the grain is combined for storage. This provides them with an opportunity to appreciate the treatment differences attained.**
    - **After harvest estimation is completed, farmers should be thanked for their assistance, and plans for the coming year discussed with them. For example, whether the same trial will be repeated, what modifications will be made, whether the same or a different location should be used, etc.**

9.8.4 Implementation of RMFI Trials

Relevant points with reference to RMFI trials are as follows:

- ***Selection of Farmers*. Farmers for these trials are selected in the same way as in RMRI trials, They are contacted individually before the beginning of the planting season. Because in RMFI trials, farmers carry out the work under the guidance of the researcher. it is extremely important that the farmer understands the differences between the treatments, what is being compared, and what is required for the different treatments and appreciates the importance of proper experimental procedures. It is also essential that the farmer has a genuine interest in the trial, so that he/she is serious about properly implementing the procedures. The farmer also must have the necessary resources to conduct the trial. Proper selection of farmers in this case requires a good deal of researcher-farmer discussion. Proper selection of participating farmers can make all the difference between successful and unsuccessful RMFl trials.**
- ***Site Selection.* As with RMRI trials, a representative location should be chosen for the trial, so that the results can be generalized. Portions of the field with big trees or stumps, paths, ant hills, and ditches should be avoided. Again, the location must be agreed upon mutually by both parties. Because part of the purpose is to examine the effect of farmer implementation of the technology, farmers must have sufficient space to simulate a real operation. In other words, they must have a sufficiently large plot so that the implementation is not very much different from the way it would be done on**

the whole field. This enables collection of 'real' socio-economic data relating to labour and traction. Where animal draught is being used, plots need to be long enough so that the animals are not turning around constantly. Also, there must be sufficient space at the end of each plot for the animals to turn without entering other experimental plots. For example in trials where animal traction is used, a plot length of 40 to 50 metres and a width of 10 to 15 metres may be satisfactory. For crop variety trials where labour or animal traction inputs are not likely to vary substantially between treatments (i.e., except for differences in time required to harvest the different yields), plot sizes can be smaller. Finally, where larger plots are used, the total number of plots must be restricted severely, so that all plots can be planted within a reasonably short period (e.g., a day).

- ***Implementation*. When conducting RMFI trials, the researcher must appreciate that the farmer its not simply someone to be given instructions on what to do. Rather, the work that the farmer is to do must be discussed and agreed upon mutually. Researchers must accommodate the other priorities of the farmer within the experimental design. Thus, although the farmer does all the implementation under the guidance of the researcher, there is a sharing of responsibilities, and the farmer plays a significant role so that he/she can be in a position to assess the potential value of the technology under practical farming conditions.**
- ***Data Collection*. The farmer should be informed during the planning of the trial what data will be collected. Before the trial work begins, it is important to decide on how to record the data collected. It is advisable to develop some standard procedures on how**

to collect the data. These procedures will help to protect the reliability of the information and to speed up the data processing and analysis.

- *Yield Estimation and Result Assessment*. It is important that the farmer understands the harvest procedures and that he/she is to compare the yields of the different plots. It is usually necessary, every year, to remind the farmers about this before harvest time and to check the procedures during and after harvest. Generally, the farmer will assess the value of the different treatments, not only in terms of yields, but also in terms of the inputs required to obtain those yields. In this type of trial, both farmer assessment and researcher judgement -- based on documented figures -- are used in the final assessment of the different treatments.

BOX 9.11: FARMER GROUPS FACILITATE TESTING A WIDE VARIETY OF TECHNOLOGICAL OPTIONS

FSD teams in Botswana have had extensive experience in using farmer groups for organizing FMFI trials. A wide range of options has been tested in such a format including:

- Tillage/water conservation techniques
- Planting method options
- Crop varieties
- Manure and fertilizer options
- Forage and fodder production options

- **Evaluation of implements**
- **Seed protection options**

9.8.5 Implementation of FMFI Trials

FMFI trials can be undertaken very conveniently through farmer groups (see Section 9.8,6). The object is to test a broad range of technologies under a wide range of conditions. As well as helping to determine what types of innovations are most appealing to farmers with a wide range of resource conditions, they provide a good way of estimating the robustness of different technologies under real farm conditions Additionally, FMFI trials provide an opportunity for involving farmers directly in the technology generation and assessment process, Points to note about a suitable procedure are as follows:

- ***Selection of Farmers*. Prior to the onset of the experimental period, research staff may attend a village meeting at which they make a formal report describing the results of the previous year's research, They also describe the plans for farmer group activities for the coming year and invite anyone wishing to participate in the farmer group to attend the first group meeting. At the first group meeting, a wide range of technology options is discussed (Box 9.11). Farmers then are asked to select any technology they wish to test. They also are invited to add to the list any items that have not been mentioned. Those farmers wanting to undertake a trial form the farmer group that meets on a regular basis (e.g., monthly), Local extension staff also are invited to attend these**

meetings, where progress and problems are discussed,

- ***Site Selection*. Farmers themselves choose the sites for their trials, However, they are asked to select sites for the test and control plots that are as similar as possible. Factors to consider in determining plot size are the same as discussed for RMFI trials (see Section 9.8.4).**
- ***Implementation*. Trial procedures are discussed at the first group meetings and are repeated in later meetings. Additionally, where necessary, village staff visit farmers to assist in the implementation. Items that are to be tested are supplied to the individuals in the groups. Any equipment being tested is given out on a loan basis. After selecting the technologies they would like to test, farmers cut pegs for marking the plots. FSD field staff visit each farmer to help in pegging each trial and to make sure that the farmers understand what they are supposed to do in terms of implementing each trial. Staff may help supervise implementation, particularly in the case of unfamiliar equipment. Field days often are held in each village, At these field clays, a selection of the participating farmers is given the opportunity to explain and show their trials to the rest of the group, as well as to farmers from outside the group, to FSD staff, to station-based researchers, and to extension staff,**
- ***Data Collection*. Because of the FMFI format of the trials, emphasis is given to obtaining farmer opinions rather than on gathering quantitative data, The farmers assess the technologies and discuss them during the regular meetings As a result, the farmers provide feedback on problems raised and, where possible, help find alternative solutions to them. Further development of PRA techniques (see Section 8.4.4) should**

increasingly enable a degree of quantification of this qualitative type data.

- *Yield Estimation and Result Assessment*. At the end of the season, the farmers harvest the plots separately to compare the yields and are helped by the field staff to weigh the produce. As in other types of trials, the farmers are allowed to keep any production from the testing work they conduct, Implements are assessed through informal discussions and by conducting a forma] end-of-season survey, through which farmers express their views on the particular item they have tested, All other trials are assessed by yield comparisons, informal discussions, and formal end-of-season surveys,

9.8.6 Farmer Groups

Because FSD teams in Botswana had a major role in developing the approach for using farmer groups in on-farm experimentation, which is summarised in a recent paper by Heinrich [1993], some time is spent here discussing its characteristics, The term 'farmer group' obviously can refer to any group of farmers who come together for any purpose, However, in the context of on-farm research in Botswana, the term farmer group has been used to signify a group of farmers who come together to test and adapt new agricultural technology options, to discuss the results of those tests, and to identify on-farm needs for other technology options, These groups are composed of farmer participants, researchers, and local extension personnel and generally meet at regular intervals throughout the cropping season. The farmers in these groups select the technologies they are interested in and test them on an individual basis under the FMFI format. They constitute a group in the

sense that they meet to discuss together on a regular basis. These group meetings are supplemented with targeted problem identification/verification visits to specific fields by the researchers themselves during the trial implementation stage.

There are three main purposes for the formation of farmer groups in on-farm research:

- ***To Expand the Range of Technologies That Can Be Examined in an' On - farm Research Programme*. Trials that involve researcher management and supervision require the researchers to spend a good deal of time on field visits. This limits the number of technologies that a research programme can test and evaluate. However, many technology options that may be useful to farmers and others have been developed on the research station and will need field testing before being released to extension. As indicated earlier (see Section 9.5.2 and Box 9.6), by using farmer groups and including farmers in the testing process, research programmes can greatly expand the number of technology options being evaluated in the target area.**
- ***To Include Farmers in the Technology Development Process*. One of the main reasons for conducting on-farm research is to include farmers in the technology development process. However, simply having researchers conducting trials on farmers' fields is not the most effective way to undertake this. In the farmer groups, the participants select the types of technologies they wish to test, they perform the tests for themselves, and they discuss and evaluate the various technology options with other farmers as well as with researchers and extension personnel. The two most important criteria used in**

judging new technology options are: how the technology performs under farmer management and the farmers' joint evaluation of the various technology options. Additionally, at the regular meetings, farmers have the opportunity to present their observations and opinions to research and extension personnel. Thus, through the farmer groups, the farmers become full partners in the technology development process.

- *To Create o Forum for Direct Interaction Between Farmers*. Researchers and Development/Extension Personnel. One of the primary objectives of FSD is to create linkages between research, development/extension, and farmers at the field level. Farmer groups bring together farmers, researchers, and extension personnel at the field level, in order to work together to develop applied technologies to increase farm productivity.

There are several ways for farmer groups to be organized. There are research-oriented and extension-oriented farmer groups [Norman et al, 1988]. Although discussion here is confined mainly to research-oriented farmer groups, many of the points apply to extension-oriented farmer groups as well.

The groups are composed of FSD researchers, extension personnel (i.e., from village, district, and regional levels), and farmers, The groups are open to any village farmer who is interested in participating, At the first meeting of the group, researchers (i.e., both station-based and on - farm) discuss a wide range of technology options, addressing as many

production constraints as possible, Farmers also are requested to raise questions about problems that they feel have not been addressed adequately. From the list of technology options that is thus developed, individual farmers select specific technology options they wish to test, However, across farms, trials of specific technology options are conducted according to a mutually agreed upon trial design. For example, it is suggested, a cowpea variety trial, if selected for testing by 10 farmers, is implemented using the same set of varieties, on the same size plots, and with the same seeding rate at all ten locations. This may allow some subsequent statistical analysis, However, if some farmers choose to deviate from that agreed plan, then that is of course, their prerogative. New equipment, small amounts of seed, and required chemical inputs are, if necessary, provided by researchers. Additionally, the researchers visit each trial once during the season to verify proper implementation, Throughout the season, the farmers, researchers, and extension agents meet as a group on a monthly basis. At these meetings, farmers discuss their progress with the trials, their observations, and any problems encountered, Possible solutions to the problems are discussed by the group.

Researchers collect data on the dates of field operations and the crop and variety used - known because of the standard trial design and the use of researcher-provided seed. The type of equipment used also is also recorded. At the end of the season, farmers harvest and sometimes research staff weigh grain yields and conduct end-of-season farmer assessment interviews. PRA interview techniques (Section 8.4.4) also could be used. These interviews are used to quantify farmer's opinions and perceptions of specific technology options (e.g., crop

genotypes). Results are reported both to farmers and to other interested researchers.

Many benefits are derived from using the farmer group approach. A few of the more Important ones are as follows:

- ***Efficiency*. Contacting farmers one by one requires a lot of travelling by researchers. Also, when dealing with individual farmers, researchers must explain their work and objectives and the technology options they are interested in testing many times over. By addressing farmers as a group, researchers not only save a great deal of travel time, but they can explain their programme to many farmers at once, thus saving time on explanations as well. By holding regular group meetings with participating farmers throughout the season, farmers, researchers, and development/extension personnel can discuss progress, problems, and farmers' observations, without the researchers having to visit each farm every month. Thus by working with groups, instead of making a lot of visits to individual farmers, researchers save both time and money that would otherwise be spent on fuel.**
- ***Expanded Range of Technologies Tested*. When using the farmer group approach, researchers can work with many more farmers than when they work only with individuals. As a result of greater participation in the testing activities, many and varying technology options can be tested.**
- ***Research-Extension Liaison*. When researchers talk with one set of farmers and development/extension personnel talk with a another set of farmers' they may form**

different ideas about farmers' problems in a region and the best solutions for those problems. However, if research and extension personnel work together at the field level and meet together with large groups of farmers on a regular basis, this problem is reduced. Working together in the farmer group approach allows research, extension, and farmers to come to a common understanding of the problems. If the same groups work together to test various technologies that address those problems, then all are able to see which technologies are useful and practical and which are not. Furthermore, if extension personnel participate in technology development, they will be in a good position to later extend the same technologies to other farmers. Thus, the farmer group approach provides a forum where researchers, extension personnel, and farmers can meet on a regular basis to address problems in the field. This interaction can be of benefit to all participants.

- ***Group Dynamics and Immediate Feedback*. An individual farmer may be reluctant to tell a researcher that a particular technology option is not good. It also may be difficult for an individual farmer to convince a researcher. However, if a group of farmers gets together before a meeting and share a common opinion of a new technology, then it is likely that someone will raise the point during the meeting. Furthermore, if one farmer tells a researcher that a particular technology is not working, the researcher may just assume that the farmer applied the technology incorrectly. This will not happen if 1() farmers at once explain that a technology option is not working. Thus, dealing with people in a group tends to help communications -- if the group is not too large -- and allows research and extension personnel to quickly obtain a practical assessment of any**

technology being tested. The groups also provide an opportunity for farmers to share opinions and observations among themselves and to develop their own solutions to problems. In societies that are not egalitarian, farmer groups probably will have to be formed for different 'classes' of people in the village, including, when necessary, different groups for men and women (Box 9.12). Also, as the group becomes bigger, productive interaction may be diminished. It is not clear at what size of group a breakdown in communication is likely to occur but, once this is known, the solution is easy -- break the group into two.

- ***Farmers Develop Their Own Production Packages*****. Farmers understand their own production problems and resource constraints better than researchers. Thus, when farmers are able to select technology options from a range of options and apply them where they wish, they often develop specific packages that are more practical than what researchers alone could have devised. Farmers also may find uses for technology items that researchers would not have considered. Thus, farmers can have a lot of input into developing improved production systems.**
- ***Farmers Teaching Farmers*****. The farmer group approach provides good material for field days. Because the trials are FMFI, the farmer who has implemented a trial is able to present it and explain it to other farmers, Farmers learn best from other farmers, so these field days can be very effective when a technology option is ready for extension.**
- ***Flexible Response to On-Station Research Needs*****. When large numbers of farmers are participating in the testing activities, it is very easy to introduce new technologies for field testing. For example, if the station-based cowpea scientists wish to get farmer**

evaluations of five new cowpea varieties, it is easy to introduce these to the groups and find farmers who want to try them. It would not be as easy if the researchers had to implement the tests themselves in several locations, Thus, the farmer group approach makes it easier for on-farm researchers to respond to the needs of on-station research programmes for field testing of their new technologies.

- *Forum for Obtaining Other Information*. These groups are effective forums for obtaining general information not only on the relevance and value of technologies being offered to farmers, but also on many other topics such as producer prices for products in an environment where there are no physical markets or market days; on aspects that affect all farmers (e.g., comments on development projects, extension, etc.); controversial issues (e.g., availability of inputs); trends (e.g., fertility, draught type, etc.): general opinions on issues; or information on variability (e.g., types of farms, farming systems, planting patterns).

BOX 9.12: FARMER GROUPS FACILITATE INTERACTION

Two very positive experiences have come from using farmer groups in Botswana:

- Members of groups have been together for some time, and, therefore, interactions between the farmers themselves and between the farmers and the 'outsiders' have become more relaxed, creating the potential for more productive discussions.
- The cultural setting is such that discussion is not inhibited between farmers in different

recommendation domains, thus creating potential for greater variability in the views expressed. Also, the majority of the individuals attending the meetings have been women, some of whom came from male-headed households .

9.8.7 A Case Study: Evolution of Farmer Groups in the Lake Zone, Tanzania

This case study is based on the experiences of Roeleveld and Colleagues 11994] in the Lake Zone FSD team in Tanzania where, like many other countries, it is still called FSR. The material presented provides a good illustration of how farmer groups can evolve over time and develop a 'life of their own' and incorporate other functions as a result of the feeling of empowerment that members appear to develop. Undoubtedly, internal group dynamics can facilitate this feeling of empowerment.

Following a participatory informal survey conducted in November 1992 by the Lake Zone FSD team, an on-farm research programme was started and resulted in the development of farmer research groups (FRGs). The survey, which was carried out in collaboration with the extension service, focused on animal husbandry, a subject not covered adequately in an earlier survey. During the survey, three villages located in one of the three agroecological zones of Kwimba District (8000 square kilometres) were visited, each one for three days. Techniques such as transect walks, village mapping, *kraal* visits, and individual and group discussions were used. Male and female farmers from various socio-economic strata of the village communities participated. Within a month after the survey, village debriefing

meetings took place to discuss survey findings and to identify an initial research topic. In the meetings, which were very well attended by both male and female farmers, proposals for research were selected. In all three villages, it was jointly decided that farmers would test an oxen-drawn weeder to alleviate the workload of men, and particularly of women, during the weeding season. A few weeks later, the first trial had started.

More farmers volunteered than could participate, because the number of weeders available were limited. Therefore, some selection was necessary. About 20 households per village could be included. Care was taken to include female-headed and non-oxen-owning households. Participants of this FMFI trial agreed to meet every two to four weeks to exchange experiences in the use of the weeder. The farmers liked this idea and decided that the 'group' should have a chairman and a secretary. This was, in fact, the start of the FRGs or in Swahili *kikundi wa wakulima watafiti*.

The village extension worker and research staff attended most of the meetings, which were organized regularly by the FRGs in two of the three villages. Attendance was high (i.e., 15 to 30 persons) with a surprisingly large number of women. Farmers were very positive about these exchanges, and discussion on subjects other than weeding quickly developed. Farmers who had not participated in the trial also started attending these one to three-hour meetings. In the third village, the development of the FRG initially stagnated because of village leadership problems, Once the villagers themselves had solved the problems, the FRG in this village also rapidly developed.

About two months after the start of the trials researchers suggested that the FRGs each organize field days to show farmers and extension workers from neighbouring villages, representatives of other FRGs, district extension personnel, and researchers the progress that had been made in ox-weeding. The results more than fulfilled expectations, The FRGs, in collaboration with their local extension workers, organized three extraordinary field days, which included talks by FRG members, field visits, and general discussions, and ended with songs and food, Transport of district staff and a few crates of soft drinks were the only contributions from the research side,

In that same season, FRG representatives visited farmers in a nearby district where ox-weeding had been introduced recently, Also, a male and a female farmer presented their experiences in a one-day workshop for extension and development staff at the district agricultural office, and all three villages participated in a presentation of the oxen-drawn weeder at the annual district agricultural show.

The first season of the ox-weeder testing ended in each village with an evaluation of the technology by male and female farmers (i.e., farmers' assessment). During these meetings, improvements in the design of next season's testing were discussed, and the meetings ended in big social gatherings with dance, music, and food. At the end of the first year, a second trial, feed supplementation of oxen, was implemented and a fourth research village added.

The second season started with village research planning meetings. Most of the participants had participated in the trials of the previous season. More trials, both agronomic and animal production related, were planned, Most experiments had been suggested by researchers but were based on problems identified during the surveys or expressed during FRG meetings. As a result of requests from female farmers, trials on sweet potato and cowpea varieties (i.e., 'women crops') were included, which mostly involved women, Despite suggestions from researchers to consider changes in the organization of the FRGs, because of the growing number of trials and participants, no changes occurred.

As a result of the increase in the research programme on the research side, little attention was paid to further development of the FRG approach during the second season. This was despite concerns regarding the 'openness' of the groups; little involvement of farmers in data collection; and some inefficiencies in the collaboration between researchers, extension workers, and FRG leaders and participants.

Despite this lack of 'active' guidance of the FRGs, they functioned well. FRG meetings continued, field days were organized for large groups of visitors, a village drama was performed during the annual agricultural show, and every trial was evaluated with farmers. Both extension staff and farmers (i.e., from the FRGs and from non-research villages) helped in testing the first extension leaflets.

Attendance at the different events was generally high. Activities for women often attracted

50 to almost a 100 persons. During the second year, the groups developed greater confidence and knowledge concerning the research done and appreciation of the actual role of 'research'. This was expressed very clearly during the many visits FRGs received from missions visiting the research station and from government officials. The FRGs organized the visitors' programme, and both men and women responded to almost all questions raised about the research undertaken.

The second year showed a number of interesting spin-offs. Four of them were as follows:

- **An active women's group was established in one of the villages. Although its members individually participated in the trials, they participated as a group in the ox- weeder trial to generate income by cultivating a rented field. The group recently has applied for credit to increase their economic activities.**
- **Another activity undertaken by tanners, independently from the research programme, was the training of farmers in nearby villages in the use of oxen-drawn weeders. This training occurred following formal requests from neighbouring villages whose farmers had seen the trials on field days, had seen the equipment operating when passing by, or had heard about it from others. Both male and female farmers have visited the villages to help in the training, indicating that both male and female farmers were trained. Attendance at training was reported to be very high.**
- **As a result of a request for training in the use of oxen-drawn weeders, from a regional Integrated Pest Management Project, 40 subject matter specialists, extension workers,**

and farmers from three districts were trained during a two-day period by one of the FRGs.

- Finally, two of the FRGs have created a revolving fund that they want to use for income-generating activities such as the supply of inputs.

Currently, the FRGs are at the start of their third season. Attempts have been made by research to organize large, dynamic, research-planning meetings in the villages in order to enlarge the number of participants and to increase participation of different user groups. With this in mind, 'technology markets' were organized in which researchers demonstrated through posters materials, demonstrations etc. what they can offer, and farmers could choose to participate in one or more of the trials. Furthermore, FRGs have agreed on the delegation of tasks and responsibilities by appointing a farmer research coordinator for each type of trial. Participating farmers will also start collecting some experimental data, a task that will be monitored by the village extension workers. Training sessions are being organized to establish this new initiative with reference to the FRGs and research/extension collaboration at the village level.

In conclusion, a promising start has been made in developing a participatory on-farm research programme. Farmers are becoming increasingly involved in the different steps of the research process, Participation in most of the activities and events is generally high, and participants are becoming more self-confident and increasingly familiar with the 'why and how' of the trials. The FRGs have started developing activities of their own, particularly in

the field of training and income generation.

Important components in the success of the FRG approach to date are believed to include the facts that the trials address major farmer-felt problems and that farmers are treated as real partners in the research process. The group approach fits well in the Sukuma culture. From the research side, emphasis currently is being placed on finding ways to ensure broad socioeconomic participation and on increasing the efficiency of the research process through better distribution of tasks among the partners, Also, increasing attention will be paid to medium-term research activities, while at the same time increasing the influence of farmers in defining the research agenda.

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10. Analysis and evaluation

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10.1 Objectives

The objectives of this final chapter are to

- **Discuss the types of analyses required in on-farm trials: technical, economic, and social.**
- **Review some of the characteristics of limited-resource families (i.e., households) and suggest what are likely to be suitable technology evaluation criteria for them.**
- **Describe some specific techniques for evaluating technologies with respect to technical feasibility, economic viability, and social acceptability.**
- **Discuss briefly some issues with respect to formulating recommendations, give an example of a specific technology in Botswana, and indicate one way to assess technology adoption.**

10.2 Trial analysis: integrated analysis

Analysis of trials is the process by which team members evaluate and interpret trial results to determine the acceptability of a technology to farmers. Through the use of various analytical techniques, trial results are examined and evaluated systematically and used to predict whether farmers will find the technology acceptable, Of course, it is also important to try and ensure that this technology is potentially equitable in terms of its impact in the sense that its adoption by some families does not result in unfavourable impacts on the livelihood of other families in the:

- **Short run -- for example, making it impossible for draught to be shared by different families.**
- **Long-run -- for example, resulting in ecological degradation.**

In the long-run, only farmers, not plants or animals, adapt and adopt new technologies, Thus, FSD workers must learn to plan, view. and evaluate their work from the farmers' perspective -- to see the world through the farmers' eyes.

Analysis and interpretation take place after a trial is completed, but the planning for analysis must occur before the trial is implemented if maximum use is to be made of information obtained in the trial. The type of analysis planned is determined by the type of trial, but the implementation of the trial is also dependent on the type of analysis to be conducted.

The objective of analysis is to provide information for an integrated interpretation of trials, which can be used in planning further FSD, identifying relevant on-station research, and/or formulating recommendations for technologies prior to dissemination.

Analysis in FSD is performed on the data generated by on-farm trials, surveys, and studies. Once the data are collected and organized, the team can apply tools from different disciplines to generate a set of disciplinary analyses, which can be considered together in an interdisciplinary framework for final analysis and interpretation (i.e., integrated analysis),

Biological analysis of trials is usually the first step in analysing the actual trial data. At this step, the team determines if the new technology represents a significant biological improvement over the traditional system, The team must decide whether the results were obtained in a 'typical, environmental setting, and so are generally applicable, or whether they were produced under 'atypical' conditions (i.e., don't reflect farmer conditions) and must be interpreted with caution.

Of course, biological evaluation by itself is an inadequate indicator of whether the technology is suitable for dissemination to farmers. As a starting point for analysis, FSD workers seek to understand the household and farming environment. An understanding of the household and farming situation is important, because it serves as a basis for judging whether a technical change represents an improvement, To assess this, three types of analysis are important,

- ***Technological analysis* is performed by the agronomist or animal scientist from the FSD team and determines if the new technology is practical in a technical sense. For example, can the farmer receive a greater yield or more animal product with the inputs and practices he/she can reasonably be expected to use with respect to the new technology?**
- ***Economic analysis* is used to determine if the farmer will receive a greater economic and more stable return from adopting the technology, Part of the economic evaluation is an assessment as to whether the farmer has enough resources available to adopt the**

technology or can acquire them by borrowing or receiving a government subsidy to facilitate adoption,

- ***Social analysis* is used to determine if the technology is acceptable within the household (i.e., intra-household) and overall village (i.e., inter-household) situation. Socio/cultural analysis looks at the technology in a whole farm, analyzes acceptability for the various members of the household who are involved with the technology, determines if there are cultural factors that influence acceptability, examines consumption/nutrition implications, etc.**

  Another consideration in the social evaluation is an environmental impact assessment (i.e., whether there are likely to be long-term beneficial or harmful effects to using a new technology). Unfortunately, to date, much FSD work does not explicitly undertake an analysis of the environmental impacts of a technology. Researchers may do this subjectively, but it is important to do it explicitly. The whole area of long-term impacts of a technology on the environment is of interest to society and also possibly to the individual farmer. For example, the effect of a cropping system on the long-term fertility of the farmer's land, its impact in increasing or decreasing soil erosion, etc., are areas that deserve more consideration than currently they usually are given.

It is extremely important to all these types of analysis to evaluate whether a technology should be disseminated or not. For example, although biological interpretation may be

made on the basis of a statistical test using a ().01 or 0.05 significance level, economic analysis may still be justified for some technologies that do not meet this level of biological significance. Two possible reasons for this include:

- **Farmers may be willing to use a new technology, even when biological research results are not statistically significant. This is particularly true when the farmer's investment is small and the potential results are relatively large.**
- **Even though the level of biological return (i.e., yield) may not be significantly greater for a new technology, there may be other benefits. such as reduced labour demand at certain times, greater reliability in return, etc., that make the technology attractive to farmers.**

All of the analyses should include and be tempered by farmers' reactions to the trial and researcher observations. The greater the degree of farmer management in a trial, the less quantitative scientific analysis is likely to be possible and the more qualitative farmer and researcher analysis will be involved. There is a continuum starting with RMRI trials, which have a large amount of quantitative data for scientific analysis, and ending with an adoption study to determine farmer acceptance after the farmers have had a chance to adopt the technology on their own.

The final step is to bring all of the individual analyses together into an integrated interpretation of the trial results, The integrated interpretation of trial results probably

should involve farmers and farm family members, FSD and on-station researchers, development/extension staff, and policy makers. Although it may not be possible to get all together in one group to discuss the interpretation of results, all have an interest in this interpretation and should be included at some point. Because different participants have different views of the benefits and costs from adopting a technology, there may not be a single all-inclusive interpretation of the results. An attempt to make an integrated interpretation, however limited, is of value to the FSD team in designing its future work plans, as well as giving the team members guidance in the question of likely adoption of the technology.

Numerous analytical tools are available to undertake the types of analysis just mentioned. The choice of tools depends on the purpose of the trial; the type of trial (RMRI, RMFI or FMFI); the data that have been collected, and the level of training of the researcher carrying out the analysis. Although many sophisticated analysis procedures are available to the researcher? they often have limitations concerning data or implementation of the procedure, which cannot be met under FSD conditions, and so are inapplicable.

The usual approach in practical FSD work is to use fairly simple procedures that are more adapted to field conditions and provide the basic information needed for interpreting trial results. Table 10.1 provides a listing of the primary tools that usually are used in the analysis process. Emphasis is on simple procedures that can be used under practical field conditions.

Even though FSD teams make use of all these types of analysis, they primarily rely on a two-pronged approach involving:

- ***Formal or Quantifiable (More Objective) Evaluation*** **-- especially with reference to technical and economic aspects -- in order to provide convincing evidence to other researchers and planners, extension/development agency staff, and those responsible for formulating recommendations.**
- ***Informal or Qualitative (Possibly More Subjective) Evaluation*** **on the part of farmers testing it -- which could be based on a large number of criteria are weighted differently,**

The following sections, do not discuss some of the standard statistical techniques listed in Table 10.1 that are used in station-based trial work (e.g., t-tests, analysis of variance, etc.) and survey work (e.g., frequency distributions, cross tabulations, chi-square tests, etc.), because they are well covered in standard statistical texts.

10.3 Suitable evaluation criteria -- farmer viewpoint

The ultimate success of a new farming technology depends on farmer evaluation, acceptance, adoption, and sustained use. Much of the success of the evaluation process hinges on selecting appropriate evaluation criteria. The difficulty of separating out these criteria is why FSD teams are increasingly advocating the two-pronged approach mentioned

above (see Section 10.2), namely both formal (i.e., quantitative) and somewhat more informal (i.e., qualitative) approaches.

TABLE 10.1: ANALYTICAL TOOLS USUALLY USED IN FSD ANALYSIS

CATEGORY OF ANALYSIS	**MEASURE OR INTERPRETATION OF**	**PRIMARY TOOLS**	
		QUANTITATIVE	**QUALITATIVE**
EX ANTE			
Technical: Biological	Effects of treatments, locations, years, and interactions	Descriptivea and t-tests	Farmer and researcher evaluation and observation
		Analysis of variance	
		Least significant differences	
		Correlations and regression	
		Modified stability (adaptability) analysis.	

Practicability			Farmer and researcher evaluation and observation
Economic	Assessment of profitability (costs and benefits), and risk	Descriptivea and t-tests	Farmer and researcher evaluation and observation
		Cross tabulation and chi- square	
		Returns to factors of production	
		Budgets -- partial and enterprise	
		Sensitivity analysis	
		Risk analysis	
		Marginal analysis	
Social	Inter-household and intra-household equity effects	Gender analysis	Farmer and researcher evaluation and observation
	Consumption/nutrition effects	Food system calendar	Farmer and researcher evaluation and observation
Environmental	Long-term impacts		Researcher evaluation

EX POST			
General acceptability	Adoption study	Adoption indices	Farmer and researcher evaluation and observation

a. Descriptive statistics are common to several types of analysis for use in summarizing and describing data. The tools include: frequency distributions; measures of central tendency (mean, median and mode); measures of dispersion (standard deviation, variance, range, coefficient of variation); and graphics (histograms, bar charts, pie charts).

The primary issue is to ensure that effective evaluation takes place before technologies are recommended for dissemination by the extension service. Obviously, the best test of the value of a technology is the degree of farmer adoption that occurs. Unfortunately, such ex post monitoring is too late to prevent wasted investment in extension training and in policy/support system services developed to handle anticipated increases in production. Therefore, FSD teams try to evaluate the value of the technology ex ante or before it is disseminated widely to the mass of small farmers. A favourable assessment is essential if an official recommendation is to be developed, As implied to some extent in earlier discussion, there are three important points in determining the success of this ex ante evaluation.

- **To the extent possible, the criteria used should be those that will be used by farmers in the target group (i.e., recommendation domain). As implied above, these are often** difficult to identify.

- Farmer assessment is potentially an important complement to formal quantitative analysis.
- The balance between an evaluation based on the criteria used by local farmers and a societal evaluation -- such as unfavourable impacts on other families and on ecological stability -- is a difficult one to strike.

To help evaluate a technology from the farmer's point of view, some questions that might be useful to ask are:

- Is the problem to be solved important to the farmer? A problem may appear to be important from the researcher's perspective, but not from the farmer's.
- Do farmers understand the trials? Technologies building on small changes in the existing system probably are most easily understood.
- Do farmers have the time, inputs, and labour required for the improved technology? Farmers evaluate the resource requirements of a new technology not only in terms of whether they have or can secure the necessary resources, but also in terms of the competing demands for the resources. In addition, different family members control different resources and so may view the technology differently.
- Does the proposed technology make sense within the present farming system? A change in one part of the farming system generally causes changes in other parts of the system. How will these secondary changes impact the system as a whole?

- **Is the mood in the region favourable for investing in new crop/livestock technologies? This may depend on how farmers view the economic and social situation in general. Is the proposed change compatible with the policy/support system that is likely to be available and with local preferences, beliefs, or community sanctions? Tastes and colour in foods, superstitions, the relation of the farming system to larger community values and activities all can effect the acceptance of a new technology.**
- **Do farmers believe the technology will continue to pay off in the long-term?**

In a more formal sense, as was mentioned earlier (see Section 3.4), it is reasonable to assume that farmers will use criteria of two types in evaluating technologies:

- **Whether they are *able* to adopt. Three factors important in determining this are:**
    - **Is it *technically feasible* for the farmers to adopt the technology, that is, are the necessary inputs readily available and can all the necessary operations be undertaken technically'?**
    - **Is the technology likely to be *economically viable* (i.e., profitable and dependable) for the farmers to adopt at the levels that will be beneficial to them? In this connection, it is important to be .sure that the proposed technology is more profitable and, hopefully, more dependable than the one it is designed to replace. In comparing technologies, it is important to determine that the proposed improvement increases the return to the most**

limiting factor. In a situation where labour or draught power are more limiting than land, it is important to look at the relative returns and dependability of those returns, in terms of the return per hour of labour or draught used during the most constraining period (e.g., the ploughing/planting bottleneck in assessing economic viability.

- **Is the technology likely to be *socially acceptable* to the farming families? For some farming families who, for example share draught power, any proposed improved technologies that require more intensive use of draught power may not be acceptable because the potential for sharing may be decreased. As discussed above, there is also an issue of what happens to within household relationships.**

- **Whether they are *willing* to adopt. Broadly speaking, will farmers be better able to achieve their goals by using the improved technology'? As indicated earlier, the criteria on which they will decide their willingness to adopt often are difficult to determine. In addition to their experience in testing it and general feeling as to whether it helps in solving problems/constraints Important to them, other factors will include the balance between preferred foodstuffs and returns to labour during one particular period of the season. Such factors are particularly difficult to relate to for those who are 'conditioned' to an experimental method that deals basically in weight per unit area of land. Indeed, several such criteria may have to be brought to bear on a single proposed change. For example, staggered planting as a practice may indicate water, labour, or** draught power scarcity, risk management, and a preference for a prolonged supply of a certain type of fresh food -- all at the same time. There is little chance of weighing these correctly in an economic analysis under the conditions in which many limited-resource farmers operate.

This difficulty in second guessing the balance in farmer evaluation criteria often has prompted FSD practitioners to argue for farmer assessment as a practical approach to technology evaluation. The FSD phase of technology development is in farmers' fields, with farmers on the spot. Yet, to date, the devices developed and used for farmer assessment are rudimentary, although, as discussed earlier (see Section 8.4.4), the use of some of the PRA techniques appears to have considerable potential. Farmer assessment is likely to be particularly useful when:

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

Improved methods for routine farmer assessment of technologies continue to need further

development and refinement, Farmer assessment has been important in FSD work. Some FSD teams have made efforts to ensure that this took place through:

- **Undertaking different types of trials reflecting various degrees of commitment on the part of farmers (see Section 9.2).**
- **Using farmer groups in assessing the values of the different types of technologies including work done at the RMRI level (see Section 9,8,6),**

This emphasis on individual farmer's criteria for technology evaluation ignores the possible impact on other farmers and on broader societal issues, which is considered in a later section (see Section 10.6).

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10.4 Technical feasibility

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10.4.1 Assessing New Equipment Prototypes

Quantitative and qualitative techniques are used to evaluate technical handling and other aspects of equipment alternatives. Typically, open-ended qualitative survey techniques are used to evaluate how well the equipment handles, to identify issues, and to discover thoughts about changes that might be made. In some cases, these assessments are combined with physical measurements (e.g., efficiency of work indicators such as dynometer readings of pulling power and work rates for a draft animal harness, or precision of work indicators such as seed placement or seed damage rates for a planter) to complete this technical evaluation,

During assessment of the operational handling aspect of alternative equipment, strategies, etc., varied reasons for poor operational handling will be encountered, such as:

- **Poor quality manufacturing,**
- **Inappropriate designs of prototype equipment,**
- **Lack of training in using unfamiliar equipment and strategies, and so forth,**

When handling problems can be foreseen clearly by FSD staff or farmer participants, it is usually advisable to make corrections or necessary adjustments before undertaking statistical testing. Assessments of operational handling may not always require a control for comparison, Controls would not be very meaningful if the experimental operation was qualitatively different from other conventional operations in the farming system.

Informal one-on-one exchanges or group discussions involving farmer participants, FSD staff,

and relevant experts are highly effective and informative methods of assessing the handling characteristics of alternative practices. PRA techniques, such as matrix scoring (see Section 8.4.4), potentially are ideally suited to quantify these informal assessments.

Even when the initial assessments of handling performance are negative, significant progress still can be made if insights and suggestions lead to better designs and pinpoint needs for instruction and farmer training.

10.4.2 Assessing the Technical Responses of Alternative Technology Options

Standard statistical techniques listed in Table 10,1, as indicated earlier (see Section 10,2), are the same as those used in station-based trial work (e.g., t-tests, analysis of variance, etc.) and are well covered in standard statistical texts, Therefore, this section simply covers some of the issues involved in choosing which statistical procedures to use in on-farm research analysis,

A number of helpful observations and suggestions have been made by various authors about quantitative evaluation techniques that pertain to FSD in particular, though no single set of standards has emerged yet, The following represent some of these observations:

- **FSD generally will not involve itself in a technology fishing expedition. Statistically speaking, this means that FSD technical assessments will place much greater emphasis on estimating levels of technical responses as opposed to testing hypotheses of**

significant difference.

- **The technical merits of technology tested in FSD should have been identified already during the ex ante screening of technology options (see Section 5,8.2). The relevance of estimating the magnitude of a difference as opposed to its statistical significance relates back to the fact that these estimates serve as the foundation for economic analyses and contribute to the formulation of judgements and opinions by farmers and experts. In consulting statistical references, the FSD worker will discover that estimating responses or the magnitude of a difference requires more observations than do simple tests of significance of differences.**
- **In most cases, multiple-mean comparison procedures, such as least significant difference (LSD) and Duncan's, should be avoided in FSD. These are procedures to explore for -- some might say to fish for -- differences when there are no firm hypotheses about which of several treatments might be superior for the measurements evaluated, In principle, FSD works with ideas obtained from farmers or from station-based research. Invariably, information exists about the technical merit of these alternatives but these are still hypotheses as far as these farming conditions are concerned. (e.g., screening a large number of varietal introductions for adaptation to a new area).**
- **Questions can be asked in research trials that will provide powerful answers, even in simple trial designs. A common interest in FSD is to evaluate two or more alternatives that can be combined and progressively form a 'technology ladder' (see Section 6.4.2). Meaningful comparisons can be incorporated into the trial design and the analysis for**

this purpose. It is always appropriate for a researcher to discuss his or her ideas, early on, with statisticians to see whether they might be improved; for example, making a trial simpler or in some other way less demanding on participating farmers.

- **A common attitude is that analysis of variance and regression tests are robust enough to handle some departure from the test assumptions about the data (e.g., homogeneous variances, normal distributions, etc.) and, as a result, the possibility of serious problems is ignored. When working in a highly variable farming environment, this attitude might be dangerous. For example, large differences in variance -- the spread between treatments on different farms -- could significantly upset a stability analysis result (see Section 10.4.3). Data can be transformed to correct this problem.**
- **A grossly under-utilized tool in FSD research is covariate analysis, As FSD work increases its emphasis on situation-specific assessments, aspects of the situation can be determined, measured, and incorporated into the analysis of the response, These technical variables, or covariates, might be physical, such as values relating to soil or weather situations, or socio-economic, such as the likelihood of a resource being available. Covariates are quantitative and continuous in nature. Some of the apparently qualitative criteria used to classify farms into recommendation domains could be represented quantitatively and used in covariate analysis.**
- **The principal objective in FSD analyses is to predict responses to farming alternatives on specific farms, at specific sites, and under specific circumstances across the target area. If FSD analyses have a predictive function, then they would tend to be characterized as follows.**

- **Predictive technical analysis will most often be based on statistical regression and related statistical techniques. However, other options exist that may become more prominent in the future (see Section 10.4.4).**
- **Two important requirements for obtaining accurate predictions of technical responses are:**

  -- That the data represent a sufficiently broad spread of environments and of the factors that affect the response. This spread must cover the full range of circumstances for which conclusions are sought. It would be highly inappropriate, for example, to make general conclusions based on responses measured only in years with below average rainfall. To achieve this spread of circumstances, numerous authors have written that in FSD work, it will be more important to include a larger number of farms rather than devote FSD and farmer resources to replications within the farm or field (see also Sections 9.5.1 and 9.5.2).
  -- That trial designs be streamlined, straightforward, and convenient, such that farmers are able to accurately implement and manage trials in a manner consistent with their own management style. In FSD, this is usually given as another argument for single replications per field or farm.

- **FSD researchers need to be vigilant in looking for variation in responses during technical**

analysis and for the possibility of unanticipated causal factors, These circumstantial responses might enable FSD to fine-tune recommendations for farmers. At the same time, a warning is in order, An initial set of responses should not be used to draw anything but a preliminary hypothesis about non-treatment factors causing a response. Doing otherwise will lead readily to spurious conclusions, if the response is related to chance or to some factor not identified properly.

If FSD researchers discover interesting responses that were not considered when the original trial was designed, these results need to be confirmed. Confirmation might include some or all of the following procedures.

- **Review results with participants. Participants with their managerial expertise often are able to verity or reject initial hypotheses,**
- **Evaluate the scientific logic of the hypothesis (i.e., possibly involving outside experts).**
- **Re-do the trial designed in a manner that the preliminary hypothesis can be tested.**

10.4.3 Modified Stability Analysis

In FSD, modified stability analysis (MSA) or adaptability analysis, as suggested recently by

Hildebrand and Russell [1994], is being used increasingly to assess the biological performance of treatments (i.e., technologies) in different technical environments. When used judiciously, this analysis also can help assess technical feasibility under different farmers' management systems.

- **Basis for Modified Stability Analysis. To better understand how these analyses are used, the basis for stability analysis is briefly examined. The performance of all treatments fall, or rise, depending on the harshness of the environment. The performance of stable treatments, however, is less susceptible to the effect of environment. The prediction of stability is achieved through the use of a statistical procedure. Estimates for statistics obtained in this procedure then are used as indicators of stability. Regression techniques are used in modified stability analysis. To date, such techniques have been underutilized in FSD work. In many respects, because of the difficulty of maintaining *ceteris paribus* conditions in experimental work undertaken at the farm level, regression analysis is intrinsically more suitable than analysis of variance in such situations [Stroup et al, 1991]**

  Stability analysis needs data from a multi-environment test. The same set of treatments is tested in each environment. Treatments could be varieties, tillage systems, and so on. Because the testing required for this procedure is expensive, having treatments without proven potential in at least one environment is not cost effective. A range of environments is obtained by conducting the test at different

locations and seasons within a country or target area. A range of environments also can be created within one site by imposing another performance factor. For example, if several irrigation regimes are implemented at one site, the set of treatments can be tested in each regime. The test needs to cover the entire range of environments envisioned by the researcher as targets for these treatments.

In on-farm research, multi-environment tests are common, The testing of a technology to improve grain yield on a range of farms, in different villages, and over several seasons gives excellent data for stability analysis.

Stability is measured from a simple linear (i.e., straight line) regression of the performance for one treatment on the index values of the environments. The environmental index is a value that is supposed to define the standard for performance in each environment. To visualize the analysis, consider a scatter diagram, The indices for environments are put on the horizontal axis and the measure of performance on the vertical axis, The environmental index points are not spaced equally. Two environments might have nearly the same index. The straight line regression shows how much change in performance of the treatment takes place for each change of the environmental index unit,

Performance of crop production treatments usually is measured as grain yield, But, performance also could be measured by other factors, such as crop establishment,

plant height, weed levels following tillage treatments, etc. Criteria important to the farmer also could be used (e.g., net return per hectare, etc.), Therefore, in a sense, modified stability analysis potentially could be used to assess more than technical performance,

The regression analysis is easy; obtaining good measures of environmental indices is not, Measurements of rainfall, soil depth, and soil pH are examples of indices that have been used in stability analyses. As an example, stability analysis could show how much the yield of a tillage system changes with each 25 millimetre increase in seasonal rainfall. More often, indices are calculated from the performance of treatments themselves. Suppose yields for double-plough planting are regressed on yields of single-plough planting in data covering 120 farmer-implemented comparisons of these systems. The 120 single-ploughing yields become 120 environmental indices. The regression can explain how much change in double-ploughing yield takes place with each 10 kilogram increase in single-ploughing yield. In this ploughing example, yield of single-ploughing is a good measure of environment when this system is the standard for that area.

Usually, in practice, the standard performance is measured as the average of several or all the treatments. Statistically, this is a problem, because Y. the dependent variable in regression, is part of X, the independent variable. Their values are automatically related. Nonetheless, the average of treatments often is

used as a measure of environmental index. Take a test of four cowpea varieties conducted on three farms in each of three villages with the test repeated for three seasons. For each of the 27 environments, the index can be calculated as the average yield of the four varieties. Stability is assessed separately for each variety by regressing variety yield on average yield.

For stability analysis to be of use, the range of environments must be adequate. Even though regression can give a prediction of outcomes for environmental indices beyond those in the data, the prediction is not likely to be accurate for environments that are far outside those of the test. Data drawn only from testing in wet seasons with high yields cannot be used to assess stability over dry and wet seasons. Data for stability analysis need to include a minimum of one environment from each end of a typical range of the indices.

In stability analysis, three regression statistics are used as indicators of stability: the coefficient of regression ('b'), the standard deviation of this coefficient (s_b), and the treatment mean.

Because 'b' indicates the slope of the regression, it explains whether the performance of a treatment improves faster, slower, or the same as the environmental index, If the environmental index is expressed in the same units as treatments (e.g., yield), 'b' equals I when treatment and index increase at the same

rate. The s_b indicates how much the researcher can rely on the regression relationship. A high s_b means that the performance of the treatment is erratic in good and poor environments. The mean, combined over environments, indicates the general ability of a treatment to perform well.

The stability or adaptation of treatments (i.e., technology) is defined as follows:

- **With good stability or general adaptation, 'b' equals 1, mean performance is high, and s_b is low. Other researchers feel that stability is highest when 'b' is less than 1 (i.e., the performance does not change much between poor and good environments), mean performance is high, and s_b is low,**
- **With good specific adaptation, 'b' is significantly different from 1 (e.g., less if adapted to poor environments and more for better environments). To be considered good specific adaptation, the performance must be relatively high in the environments for which the treatment is adapted and the s_b low.**
- **Poor adaptation is indicated by low performance means, regardless of the regression coefficient ('b') or s_b.**
- **Erratic performance is indicated by a high ski, regardless of performance mean or regression 'b'. Note that the performance of a treatment sometimes appears erratic because the treatment is interacting with factors that are not parts of the environmental index (e.g., a new sorghum hybrid does poorly in**

an otherwise good environment because of an adverse reaction to a soil factor).

- ***Adaptability Analysis*. Adaptability analysis can be used in FSD to help in dividing farms into recommendation domains (see Section 4.5 and Box 10.1). When a technology is tested under farm conditions, a number of characteristics of the farm combine to make a unique environment: soil type, farm management, and so forth. Adaptability analysis capitalizes on each environment's capability to cause a particular yield response to each treatment and then provides the data platform on which the researcher can seek 'cause and effect' explanations for these responses.**

  The steps in adaptability analysis are the following:

  - **Conduct a trial with a common set of treatments in each environment, Usually in FSD, each environment is a different farm. It is strongly advised that the set of treatments include the farmer's conventional practice as a basis for making comparisons with farm environments outside of the trial.**
  - **Regress treatment yields on the environmental index of each farm.**
  - **Differentiate treatments that are favoured in the high-yielding environments from those that are superior in the medium- and in the low-yielding environments. It should be noted that these differences, which emerge as differences in regression slopes, may not be real if statistical tests for**

difference are not significant.

- **Characterize high- and low-yielding environments further by looking for a non-experimental factor (e.g., soil factor, climatic factor, etc.) that is linked to the responses. The practical expertise of FSD staff and farmers is needed to identify factors that logically should link to different responses of trial treatments. To evaluate the factor-response relationship in an observational manner, the factor values can be plotted on the same regression graph used in the adaptability analysis. It is advisable to discuss with a statistician other tests (i.e., analysis of covariance) that might be used to assess how strong the relationship is between a factor of the environment and the trial responses. The factor that is chosen then is used to define the appropriate recommendation domains for the technologies that were tested in the trial.**

This method of sorting farm environments works quite efficiently, if the causes of high or low performance are constant from year to year. However, in some environments, variation in weather or some other factors exerts a large influence on the relative performance of many treatments, This means that the relative performances of treatments might place the farm in one recommendation domain in one year and in another domain in the next season, Therefore, the use of adaptability analysis would need more years of data in areas with highly variable weather than in growing environments with more equable weather.

BOX 10.1: MSA CAN HELP DEFINE RECOMMENDATION DOMAINS

Farmers in the Manaus District of Brazil clear forested land to plant crops such as cowpeas. Soil fertility declines quickly and, after a few seasons, the land is abandoned. Research was conducted to define appropriate soil fertilization recommendations for this zone and different circumstances in this zone [Hildebrand and Russell, 1994]. MSA was used for data collected on 13 farms that each tested four potential fertilizer packages. This included one package that was the farmer's own practice of not applying fertilizer. For these farmers, cash is scarce and the major constraint to development, so the focus when assessing response was on the criterion of kilogrammes of cowpea per dollar of cash cost.

Following a step-by-step application of MSA to this problem, two recommendation domains were delineated and factors within the environments that characterize these two domains were identified. The message for extension of this MSA is that:

- **The farmers' own practice would be appropriate in the first and second seasons after clearing land of primary forest and in the first season after clearing land of secondary forest.**
- **Chicken manure plus one-half dose of triple superphosphate fertilizer would be appropriate in later seasons and on waste land,**

Because of its high cost, a full dose of triple superphosphate fertilizer would be too risky for most farmers. If it is used, it should be used only for the first or second seasons of planting.

10.4.4 Computer-Based Simulation

As of today, the use of simulation tools is not common in FSD technical analyses. However, the use of such knowledge-engineering methods has proved helpful in evaluating alternatives in other fields. These simulations permit the users to evaluate multitudinous alternatives, at least on a preliminary basis, without investing in the implementation of real-life trials. Simulation scenarios could involve technology or management alternatives, changes in the future circumstances of farming, and so forth. Simulation programmes in the future might prove to be a very effective means of organizing FSD data. These programmes might strengthen the linkage between knowledge systems (e.g., allowing participants to effectively interface with scientific knowledge frameworks).

Simulation is a developing area, however, and good tools are not presently available for most FSD analytical work. Criticisms of contemporary simulation models for use in FSD focus on their inability to:

- **Accurately predict even biological responses over the range of circumstances encountered in real farming systems.**
- **Address aspects of farming related to human behaviour.**

Solutions to some of these problems likely will be found. It is anticipated that simulation programmes, probably supporting an iteration between machine and human participants, will become part of the arsenal of FSD analytical tools of the future, particularly with respect to FSD with a 'natural resource systems focus' and with a 'livelihood systems focus' (Section

3.3).

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10.5 Economic viability

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10.5. 1 Overview

Tools for economic analysis are probably the least known on FSD teams, which is why some time is spent in this section outlining some of the main tools. Many other references also deal with the topics in much more detail.

Most limited-resource farming households produce a mix of products for household use and sometimes for selling, Livestock (i.e., cattle or small stock) may be sold whereas basic grain production is, if not subsistence production, is at least substitution production. There are many methods for analysing potential improved technologies in a formal manner from an economic viewpoint. Three critical issues underlying the legitimacy of many of the results of

such analysis are:

- ***Measurement Problems in Doing On-Farm Trials in FSD.*** **At times, it is not possible to collect all of the data needed for an economic analysis, or the data collected are suspect. It may be necessary to make estimations of individual data values or to use coefficients for some activities (i.e., particularly labour coefficients) in order to perform a particular analysis. With integrated trial design involving all team members and close supervision of field activities, the need for making estimates and for using coefficients can be reduced. Although it may be practical to use standardized coefficients for some labour activities, for example, broadcast planting or ploughing, which are common to all technologies being tested, it is important to collect actual labour data for activities that differ between treatments, such as weeding times where there is an additional tillage operation that may reduce weed burden on one of the trial plots. Obviously, it is desirable to have all measurements as accurate as possible, but given field conditions, it may be necessary to settle for less than perfect data. Thus, the analysis performed should be appropriate for the quality of data that are collected.**
- ***Placing Correct Values on the Inputs and Products not Originating from or Ending up in the Market Place.*** **On the input side, for example, a particularly challenging issue is that of valuing family labour of which, the demand, and, therefore, the value are likely to vary seasonally. On the output side, there are many issues, for example, problems relating to valuing production consumed by household members, valuing manure from livestock that is used in production of crops, etc. However, guidelines are available on**

how to deal with these difficult issues. No matter how inputs and outputs are valued, it is important to explain carefully what has been done when reporting the results, so that others can evaluate the criteria for relevance to their situation and make adjustments accordingly.

- *The Use of Evaluation Criteria Reflecting Those Important to the Household.* Some issues relating to these have been covered in an earlier discussion (Section 10,3), One important requirement is to evaluate the results in terms of the most limiting factor, for example, return per hour used during critical bottleneck periods, rather than return per hectare. The latter is usually the major evaluation criterion used on experiment stations. Inappropriate use of such a criterion could leave researchers advocating irrelevant technologies and screening out others that could have been relevant.

As indicated earlier, techniques for economic analysis in FSD continue to be relatively simple. This is so because the relatively simple techniques are most readily understood by planners and non-economists, and because field data often are not sufficiently accurate to support complex analytical techniques. This latter reason is particularly significant where the price for most of the inputs and commodities is not determined in a market. Generally, economic analysis is carried out on the 'old' as well as the 'new, technology, in order to compare the technologies and to identify changes in the whole farm system caused by changing one part of the system.

The majority of economic analyses with reference to on-farm trial work in FSD fit in three

categories:

- ***Average Returns Analysis.*** **This analysis is the basis for most of the other analyses and consists of a listing of the average costs of producing a particular product and the average value of the product for each technology being compared. The cost- and-returns analysis requires information on both variable and fixed inputs, A more limited average variable cost-and-returns analysis often is used to compare different technologies that used the same fixed inputs. This information can be used to compare the average returns above variable costs (RAVC) (i.e., sometimes called *gross margin analysis*) for different technologies and the returns to other production factors such as total labour or ploughing labour, The process of valuing inputs and commodities its of particular importance in making realistic cost-and-return analyses.**
- ***Budget Analysis.*** **There are several types of budget analysis. The *enterprise budget* is a statement of costs-and-returns (i.e., both variable and fixed) for a particular enterprise or technology. This type of budget can be used as a building block in making *whole farm budgets* and in estimating the impact of a change to the new technology. The *partial budget,* on the other hand, is a direct comparison of the elements within enterprise budgets that change between technologies. This type of budget requires fewer data than the enterprise budget and offers the advantage of direct comparison. Finally, whole farm budgets can be used to look at allocation of resources between enterprises and at the impact of a new technology on the allocation of resources to other enterprises on a farm. The partial budget technique is used most frequently in**

FSD.

- *Risk Analysis.* When a farmer undertakes a crop or livestock enterprise, she/he always faces the risk of failure and loss of their time, cash, or other inputs invested in the enterprise. When farmers consider a new technology, they are concerned about the risk involved compared to the risk of their present technology. Measuring risk is difficult and of somewhat limited value, because different farmers look at risk differently. Risk analysis needs to be kept as simple as possible. Some indications of risk can be obtained from doing *sensitivity analysis* with partial budgets. Two additional tools used are *stochastic dominance analysis*, which assumes that farmers prefer more profit to less, and a *modified safety-fret analysis*, which provides information on the likelihood of returns from a technology falling below a minimum acceptable level.

Another type of economic analysis that is highly desirable is *marginal analysis*. Average returns and budget analysis are based on average data values acquired from a number of replications of a trial, all of which use about the same level of variable inputs. Thus, comparisons are being made between technologies based on a given level of inputs. Marginal analysis goes beyond the comparison of a given level of inputs and looks at profitability as levels of variable inputs change, This addition allows determinations as to the best (i.e., most efficient and profitable) allocation of resources for a given enterprise, Unfortunately, marginal analysis requires data over a wide range of inputs, something that is not available in much FSD work, so marginal analysis techniques, although valuable, have not been used widely, In practice, types of data required for marginal analysis are likely to

be available only from RMRI type trials, which are not a major preoccupation of FSD work.

Therefore, the type of data available will influence the type of economic analysis that is possible. In the following sections, three major types of economic analyses commonly used are described briefly, namely average returns above variable costs (i.e., gross margin) analysis, partial budgeting and sensitivity analysis, and simplified risk analysis,

10.5.2 Gross Margin Analysis

An analysis of the average (i.e., mean) costs/benefits from different technologies being examined in a trial often is made, Where all of the relevant data have been collected, this type of analysis can be used, However, this requires valuation of both fixed and variable inputs, In many cases, the variable inputs are what need to be examined, because the fixed inputs are constant for all plots in the trial, Thus, the most common analysis performed involves the average returns above variable costs (RAVC) or gross margin approach. This allows a comparison between various technologies being tested based on the inputs the farmer must provide.

The procedure for gross margin analysis is:

- **Calculate an average yield or an average amount of product for each separate technology,**
- **Calculate average inputs -- often with particular emphasis on labour inputs -- for each**

technology separately.

- **Calculate the gross return (i.e., gross total value product), which is the yield times the appropriate field price for the product or products,**
- **Calculate the variable costs associated with each technology. The variable costs for a crop trial usually include labour; seed; draught hire (i.e., if hired draught is used); and a charge for equipment depreciation.**
- **The average return above variable cost -- also called net return or gross margin -- then is calculated by subtracting the variable costs from the gross total value product.**
- **These average net returns then can be compared between technologies, Some scientists believe that the return for a new technology must be at least 30 percent higher than that for the traditional technology before farmers will be willing to consider adopting it [Zandstra et al, 1981: p. 63].**

This analysis generally is done on a per hectare basis, and the return calculated is a return to management, assuming that land is fixed and that labour has been valued at the price of its best alternative use (i.e., opportunity cost).

In order to maximize profits, it is necessary to maximize returns to the most limiting resource. For example, land may not be the most limiting resource, The most limiting resource may be traction time or labour for ploughing or weeding. When the most limiting resource is known, it is possible to calculate an average net return to that resource for the different technologies being compared and choose the most favourable technology. This

procedure will not maximize the returns, because it does not examine different levels of inputs, but it will maximize the returns to the most limiting factor for a fixed level of inputs. For example, it is possible to calculate a return to weeding labour by omitting weeding labour costs (i.e., all other labour costs are included) from the cost total and then dividing the return by the number of hours of weeding labour, giving a return per hour of weeding labour.

10.5.3 Partial Budgeting

The partial budget is a way of analysing differences in costs and benefits of two or more competing enterprises or technologies. A good start for any economic analysis of a technology, including budgeting exercises, is to make a statement of the farmers' objectives, especially as they relate to the particular farm enterprise/technology.

The second step in any budgeting exercise is to make a detailed description of the technology or enterprise. For partial budgeting, it is necessary to be concerned only with those things that change from the existing technology to the proposed one. For budgeting in general, this step includes:

- **Determining the 'unit of analysis'. The unit of analysis may be for an enterprise or technology, such as corn and bean production using an intercrop system from one hectare for one crop season, or the meat production from 100 goats for a year.**
- **Identifying of all operations that will be performed. For crops, this includes land**

preparation, tillage operations, applications of pesticides, fertilizers, etc., and marketing activities. For animals, it will include herding labour, milking, slaughtering, marketing, etc.

- Using data, where available, estimating the quantities of inputs for each operation (i.e., labour, chemicals, etc.).
- Determining the 'field price' of purchased inputs, equipment, labour, etc.' whether it is a cash cost or an opportunity cost. Multiply the price by the number of units to get a total cost for that input,
- Using data, where available, identifying the quantities of all outputs such as grain' fodder, meat, hides, etc.
- Determining a 'field price' for all outputs, whether sold or used by the household. Multiply the price by the number of units to get a total value for the particular benefit

Partial budgeting is a method of organizing data and information about the costs and benefits from some change in the technologies being used on the farm. Thus, partial budgets are useful tools for analysing small changes in farming systems and require less information than a whole farm budget or an enterprise budget, They measure changes in income and returns to limited resources; provide a limited assessment of risk; and, through sensitivity analysis, suggest a range of prices or costs at which a technology becomes profitable,

Partial budgets are not used to estimate the total income and costs for each of the technologies being considered. The goal is to estimate the difference in benefits or losses

expected from the technologies. The partial budget technique is most useful where the new technology consists of the existing technology with one or two changes. The following steps are used in creating a partial budget:

- **Identify the elements in the production process that are different (i.e., such as purchased inputs, different labour requirements, etc.).**
- **Quantify inputs that are different for the technologies.**
- **Calculate a 'field value' (i.e., quantity used times field price) for each input.**
- **Also identify, quantify, and value outputs that are different.**
- **Organize this information as outlined in Table 10.2, resulting in a presentation of information such as is given in Table 10.3,**

To interpret this partial budget (Table 10.3), note that the increase in benefits more than makes up for the reductions in benefits, Even though more costs are associated with the new technology, there is a net gain of almost P20 per hectare from using the new technology (i.e., double ploughing) over the traditional (i.e., single ploughing) technology. In its most simple interpretation, it does pay to switch from single ploughing to double ploughing in conditions similar to those where the tests took place. The change (i.e., increase) in benefits was larger than the change (i.e., increase) in costs necessary to produce that benefit.

It is also possible to look at changes that are likely to occur if prices, yields, or input requirements change. In other words, it is possible to investigate how sensitive the results

are likely to be to such changes -- a primitive measure of risk. This is done easily by setting the partial budget up on a spreadsheet such as Lotus 123. Table 10.3 shows the results that will occur if the value of labour increased or decreased by 50 percent, and what the wage rate would need to be if no increase occurred in net return from double ploughing compared with single ploughing.

TABLE 10.2: PARTIAL BUDGETING FORMAT

1. Additional benefits:	List the items of income from the new technology that will not be received from the existing technology.
2. Reduced costs:	List the items of expense for the existing technology that will be avoided with the new technology.
3. Subtotal increases	Add lines 1 and 2.
4. Reduced benefits:	List the items of income from the existing technology that will not be received from the new technology.
5. Additional costs:	List the items of expense from the new technology that are not required with the existing technology.
6. Subtotal decreases:	Add lines 4 and 5,
7. Difference	A positive (negative) difference indicates that the net benefits the existing technology by the amount shown

	of the new technology exceed (are less than) the net benefits of.

Source: Based on Boehlje and Eidman [1984: p. 237]

A partial budget is easy to interpret. However, it rarely is presented with a statement of the farmer's objectives, the farmer's resource base, and important non-cash considerations. A first consideration should be the question: does the criterion of increasing net benefit per hectare imply that it is in the farmer's interest to maximize returns to land? Often, this is not the case. The partial budget does not indicate if the draught and labour are available to the farmer to do a second ploughing, or if the farmer has the capital to hire a second ploughing, if ploughing is done through a hire arrangement. For many farmers, the availability of labour or capital may be more constraining than the availability of land. As has been repeatedly emphasized, the evaluation criterion used should maximize returns to the most constraining variable.

Although it a useful technique, there are limits to its value. Three problems that partial budgets do not address directly are:

- **While a partial budget gives an indication of which of two or more technologies is 'better', it does not answer the question as to which technology is 'the best'.**
- **The partial budget may indicate that the new technology is 'better' than the traditional technology, but it will not show that both technologies produce a loss. An enterprise**

budget would show this type of information.

- **The partial budget may indicate that a new technology is 'better' than an existing technology, but not the 'best' level at which to use the new technology. For example? feeding a supplement to dairy cattle is better than feeding no supplement, but partial budgeting will not tell how much supplement is most profitable to teed.**

TABLE 10.3: PARTIAL BUDGET: DOUBLE PLOUGHING INSTEAD OF SINGLE PLOUGHING A SINGLE HECTARE, MAHALAPYE AND FRANCISTOWN AREAS, BOTSWANA, 1983-87

ITEM	**PULA**	**PULA**
REDUCED COST (in Pula)		
Weeding time saved (6,2 hrs @ P0.38/hr)	2.36	
Single-plough harvesting time (25 hrs @ P0.38/hr)	9.50	
ADDED BENEFITS		
Double-plough yield (197 kgs @ P0.43/kg)	84.71	
SUB TOTAL INCREASES		96.57

ADDED COST		
Double-plough second ploughing (29.7 hrs @ P).38/hr)	11.29	
Depreciation on equipment	1.50	
Double-plough harvesting time (43.8 hrs @ P0.38/hr)	16.64	
REDUCED BENEFITS		
Single-plough yield (111 kgs @ P0.43/kg)	47.73	
SUB TOTAL DECREASES		77.16
NET GAIN		19.41
SENSITIVITY ANALYSIS		
Net gain when:		
Value of labour @ P0.57/hr		11.37

Value of labour @ P0.19/hr		27.44
Value of labour @ P0.84/hr		0.00

Source: Worman [1987]. Tables 10.4 to 10.6 are also derived from the same source.

10.5.4 Risk Analysis

Unfortunately, not all inputs are under the farmer's control. In Botswana, one of the most critical inputs for rainfed agriculture is soil moisture. There is a great deal of variability in rainfall between years, within years, and even between plots in the same village. This highly variable rainfall introduces a great deal of risk and/or uncertainty into the farming system. There may be other sources of risk as well, such as uncertainty about the availability of seed or traction. Farmers consider risk in their farming system and make adjustments to compensate. In Botswana, one of the traditional methods of addressing risk is to plant a large number of plots over a period of time in order to take advantage of the rains that do come. Another risk-reducing mechanism is to keep the investment of labour and cash in arable agriculture as low as possible. Thus, the farmer will not weed a plot if he/she thinks that plot will fail.

By looking at the distribution (i.e., range) of returns from experiments, it is possible to

obtain some information on how risky a particular technology may be. There are several simple tools for looking at the distribution of returns, which can help in examining the question of risk. A very primitive method was indicated in the preceding section. It was shown that partial budgets also can be used to assess risk when a sensitivity analysis is included to show expected net gains from changes in levels of certain variable inputs/outputs and/or their prices (see Table 10.3).

In the real world, no two farmers have the same attitude toward risk. Some are more inclined to take risky actions (e.g., before, during, or after the cropping season) with the ultimate hope of receiving a larger return on their investment of labour and cash. Some are less inclined to do so. When one interprets farmers' risk attitudes, it is important to assume that they realize a trade-off may exist between getting a greater return from a technology and assuring stability in the return (i.e., that there are few years with little or no return).

Farmers generally are grouped into three categories in relation to their attitudes toward risk.

- ***Risk Averse.*** **Farmers who are willing to sacrifice high expected yields and returns in order to keep the risk of low income and loss at a minimum. This type of farmer is conservative in his/her approach to decision making.**
- ***Risk Preferring.*** **Farmers who will go after the highest yields and expected returns, even though there is a good possibility that they will receive a low income or suffer a loss in**

many years. This type of farmer is liberal in his/her approach to decision-making.

- ***Risk Neutral.*** **Farmers who choose the technology with the highest expected yield or return, without considering the potential for losses.**

Farmers may fall into different groups depending on the season, the amount of resources available at that particular time, the magnitude of the cost, and the potential gains and losses from a given technology. When FSD workers interpret risk for technologies, it is important to remember that farmers will look at risk differently and so may fall into different recommendation domains based on their attitude towards the risk involved in a particular technology. However, in general, particularly with reference to major enterprises, limited- resource farmers in low income countries are likely to have a risk-averse attitude.

Generally, a farmer will have some idea of the risk of crop failure under the cropping system he/she currently uses. When considering a shift to a different cropping system, the farmer usually thinks not only of the cost of additional inputs (i.e., labour and cash) and the potential net gain in returns (i.e., whether considered in terms of yield or cash value), but also the increased or decreased risk of having a crop failure. If farmers think that risk will be increased under a new technology, they often will want to see a larger net gain from the shift to compensate for the increased risk. An increase in yield or net returns of 30 percent over the existing technology is probably the minimum increase that most farmers will consider acceptable before they adopt the technology. The opposite is also true. A perceived decrease in risk will often induce farmers to shift technologies, even if the gains from doing

so are small.

Actual measurement of farmers' risk attitudes is very complex and not practical, because the attitudes are always changing, Thus, methods for estimating risk are based on the actual data collected in trial work, rather than trying to measure farmers' attitudes toward risk,

Two simple ways of analysing risk that depend on the outcomes from trials comparing new technologies to existing technologies are as follows:

- ***Safety-First Analysis.*** **Most farmers are concerned not only with the highest yield, or return, they can get from a technology but also with the possibilities of getting little or no yield or return and, in fact, suffering a loss. Safety-first analysis looks at the results of trials comparing a new technology and a traditional technology and asks which technology will meet a chosen minimum standard -- a minimum yield or a minimum income -- most often. Alternatively, safety first can indicate which technology will produce a loss the least often. For some farmers, it is very important to have a certain amount of grain produced or the family will go hungry. For this type of farmer, it does not matter how high a yield may be possible with a new technology; if his/her family will go hungry more often under the new technology than under the old, his/her family will not switch.**

  Strictly speaking, a safety-first analysis is the probability (i.e., percentage of the time) that a technology exceeds a specified output level. Two or more technologies

can be compared, and the one that produces at least the desired output level the highest percentage of the time is preferred. A second way of looking at the same issue is to determine the percentage of the time that a technology falls below a specific minimum level that must be reached. Table 10.4 provides some data on the percentage of times that some factors, considered in singleploughing and double-ploughing trials, were above the specified minimum. It appears that double ploughing was generally better in this measure of risk than single ploughing.

- ***Other Distributional Analysis.* Although the safety-first risk-analysis method uses the distributions of trial outcomes in examining risk' it is also helpful to look at some of the traditional measures of distributions to get clues as to how the technologies will be assessed for risk. The traditional way of reporting trials data is to look at the arithmetic mean. The technology with the greater mean yield generally is preferred. However, one year of very good results, combined with several years of very poor results, may give a higher mean than several years of average results. And a farmer may prefer to have a steady return rather than one that fluctuates a great deal. Thus, it may help to look at the data in more depth.**

  One way to provide more information to the farmer is to compare the median, which is the value that is half way between the highest and the lowest value, with the mean. If the median is less than the mean, it indicates that the farmer will receive less than the mean return more than half of the time. It may be helpful to

look at how much difference there is between the mean and the median. If there is little difference, then the farmer will receive close to the mean most of the time. A lot of difference may indicate a few really good returns for the technology and many rather poor ones. Actually graphing the distribution can help in determining what is happening in the relation of means and medians. These are some indications of the skewness of a distribution.

Another potentially useful measure is the percentage of the time that a farmer can expect to receive a yield or return less than the mean yield or return. If this percentage is high, it generally indicates a situation of a few good and many poor yields or returns. Table 10.4 provides information on the mean, median, and percentage of times the yield or return was less for some single-ploughing and double-ploughing data. Although, in general, both the mean and the median were greater for the double ploughing, indicating a possible overall advantage, the percentage of the time that single ploughing was less than the mean was smaller than for double ploughing, indicating that double ploughing may be somewhat less stable.

FSD workers may want to consider using an average of the five lowest yields rather than just the lowest yield for comparison purposes. In the case of the data from Table 1().4, the lowest yield for both single ploughing and double ploughing was zero (i.e., no yield). This produced net losses of P2.70 for single ploughing and

P5.70 for double ploughing. Comparing an average of the five lowest yields gave average of 1.8 kilograms/hectare for single ploughing (i.e., average return of minus P 1 .97), whereas the five lowest yields for the double ploughing averaged 19.4 kilograms/hectare (i.e., average return of P2.90). This implies, that all other things being equal, farmers may prefer the double-ploughing technology. This method is sometimes called minimum returns analysis [CIMMYT, 1988A].

TABLE 10.4: SOME INDICATORS OF RISK, RMFI DOUBLE-PLOUGHING TRIALS, FRANCISTOWN, BOTSWANA' 1985-87

VARIABLE	N	MEAN	MEDIAN	% < MEAN	% > MINIMUM
Yield kg/ha:					70 kg/ha
Single plough	20	110	88	60	65
Double plough	20	228	191	70	75
Net return to total labour (P/hr):					P 0.38/hr
Single plough	20	0.47	0,42	55	55

Double plough	20	0.57	0.40	60	65
Net return to traction hours (P/hr):					P 0.38/hr
Single plough	20	1.64	1,07	60	50
Double plough	20	2.12	1.15	75	65

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10.6 Social/societal acceptability

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Evaluating technologies from a social/societal viewpoint has two dimensions. These are to evaluate it from the viewpoint of:

- **Relations among people in the present generation (i.e., *intra* or *within generation*)**
- **Relations between the current and future generation (i.e., *inter* or *between generation*) -- that is, ecological sustainability.**

Although individual farmers in the current generation, particularly if they are very close to the survival level, are not likely to be too concerned with intergenerational relationships, it is more difficult to separate out broader societal issues and social acceptability as far as the individual farming family is concerned with respect to intra-generational relationships, As far as the individual farming household is concerned, intra- or within-household relationships are likely to be important in assessing the social acceptability of a proposed improved technology, but such households may, or may not, be too concerned about what is likely to happen to relationships between households if the technology is adopted, Therefore, no attempt is made in the following discussion to differentiate social issues of interest to the individual farming family from the collective interests of society as a whole, In any case, individual farming households influence, and are influenced by, what is acceptable to society as a whole,

10.6.1 Present Generation Relationships

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

A couple of important intra-household social criteria include:

- ***Gender Issues*, What would be the effects of the proposed technology on other activities undertaken by women and men? For example, would more frequent weeding by women reduce time available to them for child care? Would a technology that decreases work for the men increase work for the women in the household? Thanks to the work of Feldstein, Flora, Poats, and Jiggins, methodologies have been developed in recent years to evaluate such gender issues, It is important to identify who in the household is the decision maker with reference to the enterprise or operation the technology relates to, who controls and applies the resources assigned to it, and who reaps the benefit. If the same person is not connected with all three, then complications will arise in designing relevant technologies for improving its productivity that will be attractive to all parties, For example, men could require women to work harder as a result of the introduction of a new technology in an enterprise or operation concerning which they are the decision makers and from which they themselves reap the benefit.**
- ***Short-Term Livelihood Issues*. What would be the effects of the proposed technology on the seasonal cash, resource demand, production, and consumption flows of the household? For farming households very close to the survival level, any technology that is likely to exacerbate seasonal flows with respect to any of these are likely to be socially unacceptable. With respect to the production/consumption relationship, poor seasonal synchronization between the two and the poor overall level of production**

often result in seasonal hunger. In many parts of the world, this in turn, may, result in differentiation in levels of nutrition of individuals within households, according to gender and age. The prospects of such problems, combined with the uncertainty of the climate in many areas where limited-resource farmers operate and the general low level of living, predisposes such households to implement not only strategies to try and minimize production risk but also closely related coping strategies of various types to try and maintain household security, This enables them to consume during periods when production is deficient [Frankenberger and Goldstein, 1990; Jodha,1990]. Some of these can adversely affect future productivity. Obvious examples would be selling off productive assets (e.g., animals used for draught purposes) and obtaining access to food at high rates of implicit interest (e.g., repayment in terms of labour at busy times in the farming cycle) or explicit interest, It is important to know if such coping strategies exist, whether they are among the factors determining how risk averse such households are likely to be. They also indicate how much reliability can be placed on the availability of cash for improving the productivity of the farming system, in contrast to buying food to ensure survival.

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

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

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

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

- Cultural or religious preferences for a specific crop or animal management practice. An example would be the practice of keeping animals as a store of wealth to be used in a time of need, rather than being sold on a regular basis.
- Cultural or religious taboos against specific crop management practices. An example would be having to delay ploughing at the beginning of the rainy season until the village leadership gives permission.

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

Therefore, it is important to evaluate potential improved technologies for possible negative social impacts.

10.6.2 Ecological Sustainability (i.e., Future Generation Relationships)

Another part of the societal evaluation is to determine whether the proposed technologies

contribute positively to -- or at least do not have a negative impact on -- the sustainability of the land in the long-run, However, until recently, this has received insufficient attention in evaluating technologies, Reasons for this neglect include:

- **The primary effort of FSD has been to respond to the 'felt' needs articulated by farmers. The closer farmers are to the survival level, the more likely these needs will demand fulfillment in the short-term (e.g., producing enough food to survive until next year). As a result, farmers will be less concerned about environmental degradation in the long-term,**
- **Because of responding to the 'felt' needs of farmers, much FSD work generally has a short-run focus, This is in contrast to a long-run orientation in which societal impacts become more crucial, The short-term focus, combined with the methodological complexity of incorporating societal evaluation criteria and the time required in deriving such societal impact evaluations, has meant that FSD has played a limited role in this area, Emphasis on long-term evaluation has been confined largely to subjective ex ante evaluations, Such evaluations influence choices of problems to work with and the solutions to be advocated,**
- **Most FSD, because of its institutional affiliation, tends to concentrate on the development of relevant improved technology, It is possible to develop technologies that do not have a negative impact on the environment -- particularly the agro-ecological environment, such as soils, and, to a much lesser extent, the socio-economic environment in the equitable distribution of benefits, However, it is the**

implementation of relevant policy/support systems that play an even more important role in making sure that societal goals are fulfilled,

Although recognizing the dilemmas implied by the above discussion, it is important to bear in mind that what is done now by the current generation of farmers has a bearing on what is possible in the future, A prime example of this is the issue of environmental stability recognizing the negative impact of environmental degradation on the livelihood of future farming families and possibly on the whole of society,

Current adoption of technologies and implementation of policy/support programmes can have either negative or positive influences on environmental stability. Hopefully, as discussed above, technologies developed by researchers increasingly are being screened ex ante for their possible environmental impact. In most countries, there is an explicit concern for conserving the productivity of the soil, Because of the likely short-run focus of most limited-resource farming families, conservation measures by themselves are unlikely to be very attractive to most of them, However, production does not have to be undertaken at the expense of conservation, as long as the people responsible for developing technologies and policy support programmes take conservation into consideration, through linking policies designed to encourage production with those designed to encourage conservation [Norman and Douglas, 1994],

The objective of this discussion is simply to emphasize the need to be aware of the possible

conflict between farmers' and societal needs and the importance of technology and policies supporting each other in developing a system of agriculture that will help provide satisfactory levels of living, not only for the current generation of farmers, but also for future generations. Unfortunately, appropriate methodologies for handling these types of the issues still remain to be fully developed.

10.7 Formulating recommendations

The first important point to make with reference to this topic is that the results from the evaluation procedure determine whether a recommendation is made for extending the technology through the extension service.

Information required for approving recommendations often has consisted of hard objective data collected in an RMRI experimental environment. However, there is an increasing acceptance of the need to conduct a socio-economic evaluation, as well as the more common technical analysis. To more closely approach the farmers' operational environment, much of the data required are collected best in an RMFI experimental environment. However, there is likely to be a corresponding increase in the softness of the data -- thereby, for some, potentially reducing its acceptability in the technology evaluation process. Increasing amounts of qualitative attitudinal data, collected at the FMFI level, are likely, for some, to be even more suspect in such an evaluation exercise. As has been emphasized

earlier, it is unfortunate that a move towards greater incorporation of the farmer -- the ultimate customer of trial work -- in the evaluation process has a tendency to result in a more qualitative/softer type of data that is generally less acceptable in approving official recommendations. There is obviously no easy solution to this problem, but it is apparent that a judicious mix of hard/quantitative and soft/qualitative data may be useful in the evaluation process (Box 10.2).

Scientific objectivity, requiring many years of painstaking experimental work -- often in a somewhat artificial environment -- should not be substituted completely for researcher judgement. Resources for research are limited, and ways need to be sought to maximize the return from them, so as to facilitate the agricultural development process.

With respect to this. it its important that the recommendations are formulated and passed on to extension at the earliest possible opportunity, in order to maximize their impact on the farming population. Although it is desirable to defer making recommendations until some adoption has occurred, this often results in unacceptable time delays. Rather, recommendations need to be based largely on ex ante evaluation. Because of limited research resources and diverse interests of groups using research results, it would be desirable to see a move toward devising interim best-bet recommendations, based on the best knowledge currently available to the research scientists. These should have the proviso that they can be modified in the light of further research. Of course, there is an inherent danger in doing this, especially if an interim recommendation has any possibility of adversely

affecting the environment or farmers' welfare. However, if the relevant interested parties are brought together? it should be possible to avoid drawing up inappropriate recommendations.

In an earlier section (see Section 5.9.2), mention was made of the desirability of incorporating conditional clauses and targeting information into recommendations. Much of the information needed for this process does not require exhaustive experimentation but can be derived from the knowledge and experiences of trained scientists working at the farm level. Thus, in recognizing the diversity of farmers, on-farm trials can help in developing targeted and conditional clauses for proposed improved technologies. Doing so can potentially improve the return from the limited research resources by providing a technology that is appropriate to more farmers through widening intervention possibilities. It is particularly important to develop a range of options when dealing with a difficult farming environment (Box 10,3). Such guidelines indicate how greater numbers of farmers can more closely approach the optimal situation.

BOX 10.2: USING LOCAL KNOWLEDGE TO MODIFY RECOMMENDATIONS

An experience of the Communication for Technology Transfer in Agriculture (CTTA) project in the Callejn de Huaylas, Ancash, Peru shows how technology developed on research stations can be modified in light of local needs and knowledge [Mate, 1992],

Farmers in the Callejn de Huaylas had reported that the potato worm (Premnotrypes sp.),

called 'papakuru,' was one of their most serious pests on potato, In response, station scientists developed a double chemical treatment recommendation for control of this pest, The recommendation, comprising a curator powder application at planting and a volaton treatment at hilling, placed a high demand on draught and labour during ploughing and planting and this was unacceptable.

Farmers rejected the two chemical treatment but, working with the scientists, developed a compromise recommendation, Farmers knew that rotating potatoes with maize would help in controlling 'papa-kuru,' They knew that moistened seed would develop a bitterness less palatable to the pest, They also knew that exposing ploughed soil to the sun and bird predation for a few days before planting would also reduce populations of the pest, The compromise recommendation consisted of these known measures of control as a substitute for the curator powder application at planting combined with the volaton treatment at hilling, Volaton is an insecticide that is readily available and also affordable to most farmers.

The tone of the above discussion suggests that, generally, 'blanket' type recommendations are likely to have very limited value. Much wider adoption is likely to occur, if a number of options are offered to farmers and the recommendations are tied more closely to the farmers' own production environment, Consequently, in recognition of this, there is increasingly a move away from recommendations being approved at the national level to an approach where they can be approved at a more localised level (e.g., regional) by a group

representing the different 'actors' in the agricultural development process at that level (e.g., something like a Regional Coordinating Committee (see Section 6.3.2)). Such a trend is obviously desirable, enabling decisions on recommendations to be made in a more timely manner and to be made by individuals who are more familiar with the local production environment. It is important to note, however, that a role still exists for some coordination of recommendations at the national level to:

- **Provide a documentation role in terms of the status of appropriate technology available in the country.**
- **Play a distribution role in suggesting extension of technological recommendations to other areas with similar production environments.**
- **Provide a forum or conduit for technologies that require changes in policy/support systems to facilitate their adoption (e.g., facilitating multiplication of newly approved crop varieties).**

BOX 10.3: OFFER THE FARMER OPTIONS INSTEAD OF PRESCRIPTIONS

The N.D. University of Agriculture and Technology (NDUAT), Faizabad, India, developed an on farm experimentation approach to reach resource-poor farming communities [Maurya, 1992]. Most farmers in these communities had missed the benefits of the Green Revolution with its packages of optimal recommendations.

The NDUAT approach stressed work with whole communities. It stressed the farmer's own

criteria. It stressed making options available, even when these did not appear to be the 'best' choice. The NDUAT attempted to build a new aptitude among farmers of experimentation, critical evaluation, continued innovation, and adoption as appropriate.

During an 8-year period of on-farm work, more than 700 farmers tried options in the production areas of field crops, vegetables, fruits, mushrooms, goats, pigs, and fish. The NDUAT even introduced station 'rejects' to farmers, such as genotypes that would no longer be carried by station breeding and screening programmes.

10.8 A case study: Example of double ploughing technology in Botswana

Over the years in Botswana, FSD teams did a great deal of work on double ploughing which has now been approved as a recommendation [Heinrich et al, 1990]. A summary of the results, presented in the following tables (i.e., Tables 10.5 to 10.8), illustrates many of the points made in this chapter,

Conclusions on double ploughing were that it was suitable when:

- **The first ploughing is done when planting is not possible (i.e., an option),**
- **Farmers control draught power and are faced with land constraint and/or lack labour for weeding.**
- **It is concentrated on deeper soils with higher clay fractions enabling higher water**

holding capacity (i.e., targeting information),

Later work looked at early ploughing plus other alternatives. Table 10.8 provides guidelines as to what can be done with different levels of control over traction and different types of seasons. The table contains both conditional and targeting information.

TABLE 10.5 NET RETURNS TO LAND AND LABOUR FROM GROWING SORGHUM IN DOUBLE-PLOUCHING TRIALS, FRANCISTOWN, BOTSWANA, 1985-87[a]

YEAR	YIELD (KG/HA)	ACTIVITY TIME (HRS/HA)			RETURN(P/HA)		NET RETURN (P/HOUR)		
		PREP[b]	WEED[c]	TOTAL	GROSS[d]	NET[e]	PREP	WEED	TOTAL
AVERAGE SINGLE PLOUGH									
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
Average	110	31	34	89	47.28	44.58	0.70	1.59	0.47
AVERAGE DOUBLE PLOUGH									
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	0.21	0.35

Average	228	64	43f	154	98.05	92.65	1.03	2.17	0.57

a. **Most of the data in this table are derived from results presented in Worman [1987] and involve trials for which labour data were recorded. The trials were research managed and farmer implemented (RMFI) with a sample size of 20. Planting of the single- and double- ploughed plots was done on the same day. Figures in the table are the average/plot.**
b. **Preparation time includes ploughing and planting.**
c. **Consists of weeding time only.**
d. **Gross return equals yield times price where the price of sorghum is PO.43/kg.**
e. **Net return equals gross return minus costs where costs equals seed (P0.30/kg for 4 kg) plus depreciation on equipment (estimated at P1.50/ha). In this calculation, labour has not been costed.**
f. **The difference has been the opposite way round for other trials undertaken at both Francistown and Mahalapye. From a sample size of 59 paired comparisons, the average weeding times per hectare for single and double ploughing were 34 and 19 hours, respectively. This makes the return per hour of weeding on double-ploughed plots even bettre.**

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10.9 Ways to assess adoptions

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One of the questions of interest to all members of a FSD team is to what extent farmers are adopting recommended practices. Adoption analysis can be performed on technologies that have been tested extensively in FMFI trials within ? recommendation domain and are ready for extension. The potential for adoption of the technology can be assessed by determining the adoption among the farmers who performed the final verification (FMFI) trials on the technology. It also may be of interest to know how many farmers are adopting technologies that they have been testing on a more limited scale as part of a research programme.

It is desirable to know whether farmers are likely to adopt a particular technology before it is presented on a large scale through the extension system. If farmers are not willing to adopt the technology after the final large - scale testing, it may need to be modified to increase acceptability.

TABLE 10,6: RELIABILITY OF THE RETURNS PER UNIT OF LAND AND LABOUR FROM DOUBLE PLOUGHING, FRANCISTOWN, BOTSWANA, 1985-87

CHARACTERISTIC	MAGNITUDE OF COMPARISON	PERCENT OF COMPARED COMPARISONS	
		SP	SP2b
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	30	45

	(drought relief wage)		
	Greater than P0,53/hour (minimum urban wage)	25	45
Net return per 'total' hourspent 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 10,5.
b. These results indicate the comparison for double ploughing a single hectare or single ploughing two hectares when the first hectare is planted at the time of the first ploughing. However, the combined results from this planting and from the hectare planted on the same day as double ploughing do not really provide a valid comparison with double ploughing, because it is recommended that the first ploughing be 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

There are several ways to assess the likelihood of adoption of a technology,

- **The researchers make an assessment of the adoptability of each technology through their analysis of the technological, economic, and social factors that they think are important to farmers.**
- **Observations and discussions with farmers during the course of testing, particularly during a final large-scale verification (FMFI) test, can give an indication of problems and provide the researcher with a qualitative assessment of the likelihood of adoption.**
- **A formal end-of-season survey of farmers or PRA techniques can be used to assess their plans to adopt the new technology and determine any problems encountered,**
- **The best approach is to examine actual adoption by conducting a survey one or two years following the large-scale testing of a technology to determine whether farmers who participated in the testing actually have adopted the practice and to what extent,**
- **A study of other farmers in the area (i.e., those not involved in the testing of the technology) also can be made to determine the extent of horizontal or farmer-to-farmer diffusion.**

TABLE 10.7. INFLUENCE OF SOIL TYPE ON SORGHUM GRAIN YIELD AS A RESULT OF DOUBLE PLOUGHING, MAHALAPYE, BOTSWANA, 1984-87[a]

SOIL TYPE	RANGE IN SOIL DEPTH	RANGE IN % VOL WATER	NOS, SITES	GRAIN YIELD (KG/HA)	
				DP[b]	SP

Deep medium-textured	90 - 200 cms	9 - >10	8	602 ***	354
Shallow light-textured	45 - 75 cms	5 - 9	6	266 n.s.	316

a. Data source: Researcher managed and implemented (RMRI) sorghum production factorial trial, 1984-87. Each season includes two replications.
b. * denotes statistical significance for the difference in the comparison at a 0.001 probability level, n.s denotes no significant difference,**

Source: Heinrich et al, 1990. This is also source of the material in Table 10,8.

The first three approaches above are qualitative in nature and measure farmers' intentions either as expressed or deduced by researchers. The last two approaches measure actual adoption and are quantitative in nature.

One approach to quantifying adoption is to use the index of acceptability suggested by Hildebrand and Poey [1985: pp. 122-123]. To determine the index of acceptability for a particular technology, information is collected from farmers one or two years after they have participated in large-scale testing of a technology. Farmers are asked if they are using the technology, and if so, on what proportion of the area of the particular crop for which it was recommended. An index of acceptability then can be calculated as follows:

I_a = (C x A) 100

Where:

I_a = Index of acceptability

C = The percentage of the farmers interviewed who participated in the large scale testing and who were using the technology on at least part of the crop at the time of the interview.

TABLE 10.8: GUIDELINES FOR WHEN TO USE EARLY PLOUGHING[a]

TIME OF SEASON	OPTIONS IF SOIL MOISTURE IS			COMMENTS/CONDITIONS/ TARGETS RELATED TO EARLY PLOUGHING
	OPTIMUM	MODERATE	POOR	
Early	1. EP	1. EP	1. EP	Early ploughing for owners of traction. Standard operation on a large scale for tractor owners. Animal owners must prepare teams and usually can work only part of the field.
Early-	1. PL	1. PG/PL	1. EP	Early ploughing is useful for the widest range of farmers at this

Mid	2. PG/PL			stage, even for farmers who hire traction, provided soil moisture is not the best and the farmer is certain to have further access to traction.
Mid	1. PL 2. ST/PL 3. PG/PL	1. PG/PL 2. EP	L EP	Early ploughing is becomingless useful for farmers with weaker access to ploughing and planting resources. These farmers will find it most difficult to stay on schedule with their operations and stand the greatest risk of not profiting from early ploughing.
Late	1. PL 2. ST/PI 3. PG/PL	1. PG/L		Early ploughing, even on the worst soil moisture, is generally too risky for all farmers at this late date in the season.

a. A key to the abbreviations and terms used in the table is as follows:

For seasons:	Early season:	September to early October.
	Early to mid-season:	Mid-October to end of November.
	Mid-season:	December,
	Late season:	January onwards,
For operations:	EP	Early ploughing.
	PL	Planting on early ploughed land (row planting or double ploughing).
	ST/PL	Secondary tillage before planting early ploughed land (double ploughing, cultivating, harrowing).
	PG/PL	Ploughing and planting without rainfall separating them.
For soil moisture (subjective assessment by farmer):		
	Optimum	Plant establishment is possible on existing soil moisture.
	Moderate	Intermediate.
	Poor	Plant establishment requires post-planting rainfall.

1, 2, 3 refer to different possible strategies for that particular time of season and soil moisture level.

> **A = From among those farmers who used the practice that year? the percentage of the area they planted with the new technology compared to the total area planted to the particular crop (e.g., the area planted to a new sorghum technology as a percentage of the total area planted to sorghum).**

For example, if 150 farmers participated in the test of a double-ploughing technology, and after two years a survey found that 65 were using double ploughing on at least part of the land they planted, then 'C' would be 65 . 150 = 43 percent, The average area planted using double ploughing by the 65 farmers was 4.3 hectares. These same farmers planted an average of 6.1 total hectares. Thus, 'A' would be 4,3 . 6,1 = 70 percent, The index of acceptability would be (43 x 70) .- 100 = 30,1,

BOX 10.4: ACCEPTABILITY INDICES CAN PROVIDE USEFUL INSIGHTS ON SPONTANEOUS ADOPTION

In 1989, a study of spontaneous adoption was undertaken in one region of Botswana [Wortnan, Williams et al, 19901, The degrees of adoption of a number of technologies were assessed, including double ploughing, row planting, combination of double ploughing and row planting, and use of fertilizer. These were technologies that the FSD team had tested

with farmers over the years.

The results indicated that 26 percent of the interviewed farmers had spontaneously adopted at least one of the technologies, On average, 35 percent of the crop land planted by adopters was devoted to the new technologies. Overall, the index of acceptability amounted to 9.2. Some additional insights obtained from examining the results were:

- **How complicated the technology is to implement affected the adoption. The relatively simple double-ploughing technology had an index of acceptability of 26 compared to the more complicated (i.e., requiring more management skills) row-planting technology, which had an index of acceptability of 14.**
- **As might be expected, wealth influenced adoption, Wealthier farmers were more likely to adopt technologies, with an index of acceptability of 19 for farmers owning more than 40 cattle compared to 0.7 for the poorest farmers who owned no cattle.**
- **The environment in which the household operates is important in determining adoption, with the farmers from a more 'progressive' village having an index of acceptability of 19 compared to I for the farmers from a more 'traditional' village.**

A rule of thumb for interpreting the index of acceptability is that a technology has a good chance of being adopted if I_a exceeds 25 and 'C' is equal to or greater than 50 [Hildebrand and Poey, 1985: p. 122]. This is a measure of acceptability to the farmer and does not reflect the impact of the technology. It is also important to consider the magnitude of both 'C' and

'A,, It is possible to have a very low 'C,, indicating that few farmers are adopting the technology, combined with a high 'A,, indicating that those using the technology were using it on a large portion of the land planted to the crop, This could be because a sub-group of the recommendation-domain farmers find the technology particularly valuable, although it is not accepted by most farmers, This also may indicate that different recommendation domains are present. The opposite situation, where a large number of farmers are using the technology on a small portion of the area planted to the crop, could indicate that farmers are still testing the technology, are not yet convinced that it should be 'adopted', or have adopted the technology as a component of a more complex cropping system. An additional survey in the following year may be valuable in assessing the adoption, or some modification may be necessary to promote adoption.

The index of acceptability procedure is designed for analysing the adoption of a particular technology, usually for a single crop, for farmers in a specific recommendation domain (Box 10.4), If it is used to measure adoption under other circumstances, such as a measure of spontaneous adoption on a range of new technologies, the interpretation of the results will be different, and the numbers suggested above probably will not be relevant. Instead, comparison of the index of acceptability between technologies or by farmer characteristics (i.e., indicating possible recommendation domain delineations) may be of value.

Finally, as indicated in an earlier section (Section 5.10.2) increasing emphasis is being placed now on looking at the impact of research as a whole. Adoption of technologies developed

earlier by the research system and disseminated through the extension system is considered an important indicator of the return from such investments. Methodologies for undertaking such studies now are becoming readily available -- see, for example, CIMMYT [1993].

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Part IV - Appendices

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Appendices are devoted to the following:

- **Listing some references on FSD including some not earlier cited in the manual (Appendix A1).**
- **Defining the acronyms used in the manual (Appendix A2),**
- **Using the Botswana semi-arid production environment as a base to indicate how data on two of the most important technical variables (i.e., plant densities and yields) are collected (Appendix A3).**

Appendix A1: References on FSD

This appendix is divided into two sections as follows:

- **The first section consists of the references cited in the main body of the text (Section A I , 1),**
- **The second section consists of some additional references that considered to be useful to FSD practitioners but were not cited in the manual (Section A1.2).**

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Appendix A2: Definitions of acronyms

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av	Average

BM	Bigroot Morningglory
CAPRO	Chief Animal Production Research Officer
CARO	Chief Arable Research Officer
CATIE	ropical Agronomic Center for Teaching and Research
CGIAR	Consultative Group for International Agricultural Research
CIAT	International Centre for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Centre
CIRAD	Centre de Cooperation Internationale en Recherche Agronomique pour le dveloppement
CC	Common Crupina
cms	Centimetres
CRD	Completely Randomized Design
CNRD	Continuous Non-Registered Data
CTTA	Communication for Technology Transfer in Agriculture
CV	Coefficient of Variation
DDC	District Development Committee
FAO	Food and Agricultural Organisation

FMFI	Farmer Managed and Implemented
FPR	Farmer Participatory Research
FRG	Farmer Research Group
FS	Farming Systems
FSAR	Farming Systems Approach to Research
FSD	Farming systems Development
FSR	Farming Systems Research
FSR and D	Farming Systems Research and Development
FSR/E	Farming Systems Research and Extension
FSSP	Farming Systems Support Project
FSW	Farming Systems Work
FTP	Forest, Trees, and People Network
GIS	Geographic Information System
ha	Hectare
hr	Hour
ICLARM	International Centre for Aquatic Resource Management
ICRAF	International Council for Research on Agroforestry

ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Centre
IDS	Institute of Development Studies
IIED	International Institute for Environment and Development
IITA	International Institute of Tropical Agriculture
ILEIA	Information Centre for Low External Input Agriculture
IRRI	International Rice Research Institute
IRS	Intensive Residential Study
ISNAR	International Service for National Agricultural Research
kg	Kilogram
LS	Leafy Spurge
LSD	Least Significant Difference
m	Metre
MSA	Modified Stability Analysis
NARS	National Agricultural Research System
NDUAT	The N.D. University of Agriculture and Technology
NGO	Non-Governmental Organisation

OFR/FSP	On-Farm Research with a Farming Systems Perspective
PA	Palmer Amaranth
PRA	Participatory Rural Appraisal
PFI	Practical Farmers of lowa
PSP	Production Systems Programme
RAVC	Returns above Variable Costs
RCBD	Randomized Complete Block Design
RCC	Regional Coordinating Committee
RDBM	Relational Database Management
RRA	Rapid Rural Appraisal
RMFI	Researcher Managed and Farmer Implemented
RMRI	Researcher Managed and Researcher Implemented
RRA	Rapid Rural Appraisal
SIDA	Swedish International Development Agency
SPRD	Single Point Registered Data
SUAS	Swedish University of Agricultural Sciences
UK	United Kingdom

USAID	United States Agency of International Development
USA	United States of America

Appendix A3: Estimating crop densities and yields

In FSD trial work measurement of crop densities and yields are often two of the most important activities. The following sections illustrate the complexity of such activities and, in doing so, also indicate the necessity of often having to adjust the methodology to the local situation, in this case to the semi-arid climate of Botswana.

A3.1 Introduction and use of density measurement

After grain yield, plant density is the most important direct measurement in on-farm crop trials. Plant populations vary greatly among planted areas in Botswana. Different technologies and other causes can influence the percent of seeds sown that emerge and become useful plants. In FSD, plant density measurements are used to estimate the percent field emergence.

The FSD researcher should measure plant density when most of the plants of the eventual

crop stand are emerged and established. Establishment is a relative term, but with sorghum it is usually four to six weeks after first emergence. Established plants generally have sent roots into the sub-soil below the ploughing layer. The researcher often wishes to measure the percentage of seeds sown that became established as the response variable. Two ways to calculate percent field emergence are:

- **When it is assumed that all the seeds sown are viable:**

  Percent field emergence = [100 x crop stand (plants/ha)] / number seeds (seeds/ha)

- **When a seed viability test is conducted to test the percent of seed that can germinate:**

  Percent field emergence = [100 x crop stand (plants/ha) x % seed viable] / number seed (seeds/ha)

  Note: Researchers not farmers, usually measure population density. When it is not possible or desirable to conduct a stand count for a whole plot, it is necessary to use some sampling procedure. FSD staff in Botswana frequently use the systematic quadrat sampling technique, In the following sub-sections, this method plus several of its variants is discussed,

A3.2 Measuring plant densities

A3.2. 1 Systematic Quadrat Sampling for Broadcast Planting

The procedure consists of the following steps:

- ***Sub-Sampling*. Sub-sample the plot with a 2m by 2m quadrat. Take 20 quadrat sub samples in a systematic pattern. Usually, this pattern consists of two passes through the plot each with 10 equally spaced sub-samples. Preferably, two people carry the quadrat, count plants, and record data. The front carrier follows a sampling line and the rear carrier counts paces. The rear carrier places the quadrat on the ground, without bias, at the point of his or her toe,**
- ***Data Collection*. In each sub-sample, count and record the number of plants of the crop,**
- ***Calculate Crop Stand*. This is done as follows:**

  Crop stand (plants/ha) = [average number plants per quadrat x 10,000 quadrat length (metres)] / quadrat width (metres)

  For example, if there is an average of 8.3 sorghum plants per sub-sample and a quadrat sub-sample of 2m by 2m, the:

  Crop stand (plants/ha) = (8.3 x 10,000)/(2 x 2) = 20,750 plants/ha.

Note: When the shape of the plot is long and narrow or of another irregular shape, the sub-sampling pattern should be such that quadrat sub-samples are spaced as equally throughout the plot as is possible.

A3.2.2 Systematic Quadrat Sampling for Row Planting

- **Sub-Sampling. Sub-sampling for row-planted plots is similar to that for broadcast planting. The pattern for rows consists of two passes, each with 10 equally spaced sub samples. Each pass follows rows near, but not on, the border, Therefore, select rows that are one-fourth of the plot width from the border.**
- **Data Collection. The procedure is similar to that for broadcast plots. The main difference is that for row planting, the number of rows in each sub- sample is recorded. The number of rows sampled should remain the same for all sub-samples in a plot. When row spacing is 0,75 metres, two rows should be included in each sub- sample,**
- **Calculate Crop Stand. This is done as follows:**

Crop stand (plants/ha) = [average number plants per quadrat x 10,000] / [number rows in quadrat x quadrat length (metres) x row spacing (metres)]

For example, with an average of 7.4 sorghum plants per sub-sample, when each quadrat sub-sample is 2m x 2m, with an average row spacing of 0,75 metres, and two rows in the sub-sample, then the:

Crop stand (plants/ha) = (7,4 x 10,000)/(2 x 2 x ().75) = 24,667 plants/ha.

Note: Researchers should avoid sampling in rows where the plant stand is unusual due to a cause other than the treatment. The most common example is blockage of a planter during one pass through the plot. When this problem is observed, a neighbouring, but not adjacent, row is sampled.

A3.2.3 Row Segment Measurement for Row Planting

- ***Sub-Sampling*. Sub-sampling is on segments of rows. This method is similar to the systematic quadrat method for row planting The main difference is the use of a measuring stick or measuring string to mark the row segment instead of a square quadrat.**
- ***Data Collection*. Data collection is also similar to that of the systematic quadrat method for row planting. The segment length is recorded as the length of the stick or other measuring device used.**
- ***Calculate Crop Stand*. This is done as follows:**

Crop stand (plants/ha) = [average number plants per segment x 10,000] / [segment length (metres) x row spacing (metres)]

For example, with an average of 21.4 sorghum plants per segment sample, each segment having a length of 1() metres, and average row spacing of 0.75 metres,

then the:

Crop stand (plants/ha) = (21.4 x 10,000)/(10 x 0.75) = 28,533 plants/ha.

If more than one row in the segment sub-sample is included, then:

Crop stand (plants/ha) = [average number plants per segment x 10,000] / [segment length (metres) x row spacing (metres) x number of rows]

Note: Researchers who use this method must check that the measuring stick does not slide out of position when they make their plant counts.

A3.2.4 Methods for Mixed Cropping in a Broadcast Planting

Use the method described for systematic quadrat sub-sampling for broadcast planting (see Section A3.2.1). When crops are mixed, the researcher must record the number of plants separately for each crop that he or she identifies in a sub-sample. A crop stand for each crop in the mixture and for the combined mixture is calculated.

Note: Mixed cropping situations happen in many on-farm trials. Volunteer watermelons, cowpeas, and other crops commonly establish in sorghum trials. In experiments controlled by the farmer, these volunteers should be left and counted. In other experiments, where agronomic data are more important, the

researcher may wish to remove these plants. The researcher should not count the removed plants.

For example, if there is an average of 8,3 sorghum plants and an average of 0,9 watermelon plants per sub-sample and a quadrat sub-sample of 2m by 2m, the:

Sorghum stand (plants/ha) = (8,3 x 10,000)/(2 x 2) = 20,750 plants/ha

And the:

Watermelon stand (plants/ha) = (0,9 x 10,000)/(2 x 2) = 2,250 plants/ha

Therefore:

Intercrop stand (plants/ha) = 20,750 sorghum plants + 2,250 watermelon plants/ha.

A3.2.5 Methods for Mixed Cropping in a Row Planting (intercropping)

Use the method described for row segment measurement for row planting (see Section A3.2.3), The researcher sub-samples or counts each crop in the intercrop and records these data separately, Usually, the segment samples for one crop are paired with segment samples for the other crop. Record the proportion of intercrop rows occupied by each crop.

Stand for each crop (plants/ha) = [average number plants per segment x proportion of rows x 10,000] / [segment length (metres) x row spacing (metres)]

Stand for the intercrop (plants/ha) = ((average number plants of first crop per segment x proportion of rows) + (average number plants of second crop per segment x proportion of rows) x 10,000)/(segment length (metres) x row spacing (metres))

Take the example of a two-row sorghum to one-row cowpea intercrop. Research staff count an average of 18.4 sorghum plants per segment sample and an average of 12.6 cowpea plants per segment sample. Each segment has a length of 8 metres, The average row spacing is 0.82 metres.

The sorghum stand = (18.4 x 0.67 x 10,000)/(8 x 0,82) = 18,793 plants/ha

The cowpea stand = (12,6 x 0,33 x 10,000)/(8 x 0,82) = 6,338 plants/ha

The intercrop stand = [((18.4 x 0,67) + (12,6 x 0,33) x 10,000)] / (8,0 x 0,82) = 25,131 plants/ha

Note: The inter-crop stand equals the sorghum stand plus the cowpea stand.

A3.2.6 Percent Ground Cover as an Alternate Measurement

Percent ground cover can be used as an alternative to plant counts in some situations. It is often preferable to estimate weed growth by percent ground cover than by plant counts. This is because weed plants differ enormously in size per plant, Spreading crops such as watermelon, pumpkin, and indeterminate cowpea also might be measured as ground cover instead of plant number.

On-farm researchers in Botswana use percent ground cover to measure weed growth before ploughing, weed growth at weeding time, weed growth late in the season, and watermelon growth in a sorghum-melon mix. Researchers use two different cover-estimation methods:

- ***Whole Plot Method*. FSD researchers estimate visually the percent of ground covered by vegetation. The estimate is from 0 percent (no ground cover) to 100 percent (when vegetation cover equals the ground area). The researcher stands at one end of the plot to make the estimate. If the plot is long, the researcher divides the length into equal parts and estimates percent cover for each division of the plot. The plot estimate is the average of all division estimates.**
- ***Quadrat Sub-Sampling Method*. The ground cover is estimated using two quadrat sub sampling methods. For each method, quadrats are used that measure 2m by 2m:**

    - ***Method 1*: The quadrats remain at fixed positions in the plot. The positions represent different parts of the plot, This method is used when repeated measures of cover are needed. Because of the time and material costs of**

maintenance, work is usually to confined to a very few fixed quadrats (e.g., two to four per plot). Again, a visual estimate (i.e., 0 to 100 percent) of the percent of ground covered by vegetation is usually made.

- ***Method 2*: Quadrats are placed for one measurement only. Sub-sampling is similar to that for systematic quadrat sub-sampling for broadcast planting, (Section A3.2. 1). The same visual estimate of the percent of ground cover is usually made.**

Additional points to note are:

- **Contrary to conventional wisdom, estimates of a percent cover are better than a simpler rating of cover, even if precision of the percentage seems suspect. Compare a 0 to 10 rating system with a 0 to 100 percent system. Some researchers may never differentiate better than between ratings of six or seven. Even then, nothing would be lost in using percent estimates, because true differentiation is still between 60 and 70 percent. Other researchers are able to differentiate better than between a six or seven rating particularly near the zero or 10 extremes. For these researchers, the 0 to 100 percent estimate is more precise.**
- **Accuracy, precision, and consistency between researchers will be improved with simple training on estimating percent ground cover. Even after training, several different staff members are asked to cross-check estimates on some of**

the same plots, Experience shows that a core of staff can be identified to give repeatable estimates of percent ground cover,

The following situation occurs commonly in on-farm research, Suppose there is a need to know the sorghum plant density as well as the ground cover provided by a secondary intercrop or by weeds. Using systematic quadrat sampling (see Section A3.2.1), the following were found: an average of 8,3 sorghum plants and an average watermelon plant cover (i.e., Method 2 above) of 62% per sub-sample, the:

Intercrop stand = 20,750 sorghum plants/ha, + 62% watermelon ground cover,

A3.3 Introduction to crop yield estimation

Yield is the most important direct measurement in crop experiments, In this section, methods that are used to measure crop yield in on-farm research are discussed, Over the years, these methods have been used and modified to suit the needs of work in Botswana. The methods vary, because requirements of experiments differ. Researchers should thoughtfully select the appropriate method for each experiment in their programme.

Once a method is selected, it should be used throughout the trial or experiment. This can ensure that differences in the data are a result of treatments and not of a change in research methods. If circumstances require a change, the change should take place between

replications and not between treatments. Treatments in a replication must be handled in a uniform manner.

Not only methods, but personnel and equipment, cause bias in a yield measurement, if one treatment is favoured. Farmers or staff sometimes have a preferred treatment. When this happens, the data become biased and possibly invalid. Training of staff and farmers helps avoid bias caused by uneven use of measuring methods,

The researcher will choose a method for several reasons: speed, ease, cost, information needed, precision needed, nature of crop or crop mixture, and design of the trial, The researcher must also remember that yield measurement, whether by researcher or farmer, should be handled in a way that does not greatly inconvenience the farmer.

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A3.4 Yield measurements of sorghum and millet plots

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The method used must be appropriate for sorghum and millet trials. In contrast to trials on legumes, most sorghum and millet trials focus on production practices. A single variety with a relatively uniform maturity is planted. This means that yield usually can be measured with a single cutting. Plots for trials on tillage-planting and water conservation tend to be large, which increases the size of the harvest. The method also needs to be quick, because sorghum and millet plots tend to be numerous in on-farm research.

All sorghum and millet trials are not the same. Some consist of a large number of plots in a field, whereas others include only two or three plots, The participation of farmers is generally more in simple experiments than in those with a larger number of plots in the field.

A3.4.1 Systematic Quadrat Sub-Sampling for Sorghum and Millet

The procedure, which can be used for both broadcast and row-planted plots, can be used to make fairly accurate estimates of grain yield during a single visit by researchers to the field. This procedure is especially useful for production systems in which harvests are typically carried out in stages. This procedure is remarkably accurate in the Botswana production situation because much more of the variability in sorghum and millet grain yields is due to head numbers per hectare than to average weight per head. The procedure is as follows:

- ***Sub-Sampling*. Sub-sample the plot with a 2m by 2m quadrat. Take 20 quadrat sub samples in a systematic pattern. Usually, this pattern consists of two passes through**

the plot with 10 equally spaced sub-samples. If the plot is row planted, each pass follows rows near, but not on, the border. In such a case, select rows that are one-fourth of the plot width from the border on both sides of the plot. Preferably, three people work: two carry the quadrat, and one carries the sample bags and records data. The front carrier follows a sampling line and the rear carrier counts paces. The quadrat is placed on the ground, without bias, at the toe of the rear carrier. For row planting, record the number of rows in each sub-sample and average row spacing in each plot.

- ***Data and Sample Collection*. In each sub-sample, counts are made on the number of plants and number of grain heads. Heads are recorded as:**

HR -- Heads already harvested before measurement.
MT -- Heads ready for harvest.
GR -- Heads that are green. These can reach maturity.
GZ -- Heads that are completely missing due to livestock feeding.

At this point, there are two options:

  - **Option 1: Harvest the MT heads and put them in large, brown kraft paper bags. Labelling includes field, plot, and quadrat number. Close and staple bags. Pack sample bags from plot in a large burlap bag.**
  - **Option 2: Harvest the MT heads and bulk all sub-samples from the plot in a large burlap bag. This is the option now recommended.**

- ***Drying, Threshing, and Weighing Samples*. Which approach to use here is based on the options used above:**

    - **Option 1: Oven dry or sun dry the sub-samples. For sun drying, the heads should be removed from the bag. For this option, a protected space is required, reached by the sun, in which to spread and dry the samples. Alternatively, heads may be left in the bags to dry, but the bags must be opened fully. When the samples are left in the bags, drying will take a little longer, but it reduces the danger of samples getting mixed up or lost, When samples reach a uniform threshing moisture, the heads are counted and threshed, grain weighed, and the data recorded on the harvest data sheet, A labelled bag is used to hold a sample throughout the final weighing process.**
    - **Option 2: If the grain is wet, it is first dried, and then bulked sub-samples are threshed and weighed at the farm,**

Additional points to note are:

- **If a plot has been harvested already, FSD staff still can collect a sample of 30 heads that the farmer indicates came from the plot, Check carefully with the farmer about this, When the plot is harvested, a rough estimate of yield can be made by using this head sample and HR counts in the field.**
- **Other measurements can be combined with quadrat sampling, such as plant**

height, visual gauging of average height of productive plants to the base of the main panicle, etc.

- **Systematic sub-sampling appears complicated, but experience has shown that research technicians and casual labourers can routinely and correctly handle the method, A training session for technicians improves the quality of sub sampling, When farmers harvest trials, sub-sampling should not be used.**
- **Sub-sampling is appropriate for RMRI or RMFI trials where the number of plots per field is greatest, With this method, the researcher can gather in-depth agronomic information, such as sorghum tiller numbers and head size in a RMFI manure trial, which is needed for some comparisons with station research. Sub sampling can estimate more precisely the effect of treatments than whole-plot harvest, This is because:**

  -- Plot size and shape are not regular. Inaccurate estimates of plot size affect whole-plot measurements, but not quadrat measurements.
  -- Non-treatment causes often mask treatment effects in portions of plots. Such visible conditions as ploughing dead furrows, plot borders, water washouts, ant hills, and trees can be avoided by sub-sampling.

- **Harvesting by research staff can have a negative effect on the farmer's view of the trials. To help with implementation and assessment of experimental technology, researchers should strive to pass ownership of farmer-**

implemented trials to farmers, Farmers gain a greater sense of ownership if they harvest their own trials,

- ***Calculate Yield*. Grain yield estimates, tiller numbers, and head weights are most easily calculated by entering the data in dBase 3 Plus database package and using the program that is described in Norman and Siebert [1990], Alternatively, grain yield can be calculated by the following formula:**

Average head weight (kg) = total weight in sample of heads taken (kg) / number of heads

Total potential grain yield (kg/ha) = (av. head weight x av. number HR heads) + (av. head weight x av. number MT heads) + (av. head weight x av. number GZ heads)

'Potential' is indicated because the GZ heads have been eaten by animals and are not available to the farmer for harvest.

Total grain yield for farmer (kg/ha) = (av. head weight x av. number HR heads) + (av. head weight x av. number MT heads)

Note: An estimate of harvest from heads that are still green can be added if the visit is relatively early and the researcher and farmer believe that the green heads will develop and be harvested at a later date,

Grain yield from green heads (kg/ha) = (av. head weight x av. number GR heads)

For example, FSD staff find several large plots in which about half of the sorghum is ready for harvest but still in the field, The farmer has harvested the earliest heads to prevent damage from wild animals. Using the systematic quadrat subsampling method (see Section A3.4.1), FSD staff count on an average of 5,8 plants/quadrat, averages of 8.5 MT heads/quadrat in the field, 2.2 HR stems/quadrat indicating heads that have been harvested, 3.7 GZ stems/quadrat showing signs of animal grazing of heads, and 5.5 GR heads/quadrat that should still mature and be harvested. The FSD staff harvests the MT heads from the subsamples and collects a sample of HR heads from the threshing floor as directed by the farmer. The MT heads weigh an average of 0.032 kg and the HR heads an average of 0.015 kg. Note that the HR head weight is used for GZ or previously grazed heads, as well. Each quadrat sub-sample is 2m by 2m,

Harvest plant stand (plants/ha.) = (5.8 x 10000)/4 = 14,500 plants/ha

The MT harvest (kg/ha) = ((8,5 x 10000)/4) x 0,032) = 680 kg./ha

The HR harvest (kg/ha) = ((2.2 x 10000)/4) x 0.015) = 83 kg/ha

The GR harvest (kg/ha) = ((5.5 x 10000)/4) x 0.032) = 440 kg/ha

The GZ harvest (kg/ha) = ((3,7 x 10000)/4) x 0.015) = 139 kg/ha

The actual harvest to the farmer (kg/ha) = MT + HR + GR = 1,203 kg/ha

If it is discovered later, for whatever reason, that the field was abandoned before the GR heads matured, the actual harvest = MT + HR = 763 kg/ha.

The harvest that was lost to uncontrolled animals = GZ = 139 kg/ha,

A3.4.2 Whole-Plot Harvest for Sorghum and Millet

- ***Measure Size and Shape of Plot*. Re-measure at the end of the season for RMRI and RMFI trials, For FMFI trials, the researcher may decide that pegging from the beginning of the season is accurate enough.**
- ***Row Planting*. Measure average row spacing, if the plot is row planted. Average row spacing equals the width of the plot in metres divided by the number of rows in the plot.**
- ***Plot Boundaries*. Where they are not clear, plot boundaries need to be marked, In large plots, tall sighting poles help greatly in marking boundaries, In small- and intermediate sized plots, string lines can be used to mark boundaries. Because the need for precise marking is less in FMFI trials, decisions about boundaries usually can be left to the host farmer.**
- ***Farmer Harvesting*. Discuss the needs of the trial with the farmer if he/she will be harvesting alone, When research staff are helping with the harvest, discuss the schedule with the farmer, Arrange logistics, such as where the harvest from the plots will be**

stacked for drying, If possible, researcher or field staff should visit the field on the day when the farmer starts harvesting. At that time, they should label the harvest bags and agree on which bags will be used for each plot.

- *Harvest Criteria*. Instruct harvesters on the criteria for harvesting, such as whether to harvest green millet heads, heads with smut, and so on.
- *Single Cutting*. Usually plan to harvest a plot in a single cutting. If more than one cutting is planned, adjust the harvest criteria appropriately.
- *Threshing and Weighing*. After drying, thresh and weigh grain from each plot. The farmer is asked to transport the harvest of each plot to the threshing floor, thresh the grain, and put it in a labelled bag. Researchers provide the farmer with bags, Identification on the bag must be simple and clear, Research staff will schedule a visit to weigh the threshed harvest from each plot,
- *Calculate Yield*. This is done as follows:

Grain yield (kg/ha) = (plot yield (kg) x 10,000)/plot size in square metres,

For example, if 18 kilograms are harvested and the plot size is 10m by 25m metres, then:

Grain yield (kg/ha) = (18 kg x 10,000)/(10 metres x 25 metres) = 720 kg/ha,

Additional points to note are:

- **Whole-plot harvesting is easy, inexpensive, and appropriate for FMFI trials. That is why this method is recommended when farmers harvest trials alone or together with research staff. Because farmers are helping with harvesting, a larger number of research sites can be managed, If farmers work with the harvest, they also are more likely to feel they own the trial.**
- **The additional work required to make the whole-plot method precise enough for some studies can be tedious, Plot size and shape must be measured accurately. Sometimes, portions of the plot affected by causes from outside the trial need to be subtracted from the plot area before calculating yield.**
- **This method is most suitable with small- and intermediate-sized plots, Keeping many harvest samples of large plots separate is difficult, and the chance of a mix-up increases. Using this method, the researcher cannot easily collect the data to make in-depth agronomic analyses. Information on tiller number and harvest plant stands would need separate sampling and measurement.**

A3.4.3 Row-Segment Measurement for Sorghum and Millet

- ***Sub-Sampling*. Sub-sampling and data collection are similar to those of the systematic quadrat sub-sampling method (see Section A3.4.1). The main difference is the use of a measuring stick instead of a square quadrat.**
- ***Sample Collection*. Cutting, drying, threshing, and weighing samples are the same as for**

Option 2 of systematic quadrat sub-sampling (see Section A3.4.1).

- ***Calculate Yield*. Grain yield estimates can be calculated by using the following equation:**

Grain yield (kg/ha) = [(sample Yield per plot (kg) x 10,000)] / [(number sub-samples x segment length (metres) x row spacing (metres)]

For example, if 2 kilograms are harvested from 20 measured segments in a plot, each segment is 2 metres long, and average row spacing is 0.75 metres then:

Grain yield (kg/ha) = (2 x 10,000)/(20 x 2 x 0.75) = 667 kg/ha.

Note the following additional points:

- **Because this method is similar to the systematic quadrat sub- sampling method, most comments given in that section (Section A3.4.1) pertain here as well. Tiller number and head weights also can be calculated,**
- **The use of a measuring stick instead of a quadrat has three effects:**

  -- The stick is more manageable, so work can be done by two technicians instead of three.
  -- The stick is easy to transport -- a big plus for staff travelling on bicycle or foot.
  -- However, the quadrat is more decisive than the stick about defining

the boundary of the sub-sample. Harvest data collected with quadrats are generally more reliable than data collected with measuring sticks.

A3.5 Yield measurements of legume plots

A3.5.1 Whole-Plot Approach

Several reasons why whole-plot harvesting is used to measure grain yield in onfarm legume trials are:

- **A major part of on-farm work with cowpea, mung bean, and groundnut has been testing varieties and other crop comparisons. In these trials, plots can be distinguished readily by plant or seed type,**
- **Legume plots are not big; trials include only a few plots per farm and tend to be FMFI. Farmers can readily manage the whole-plot harvest of this type of trial.**
- **Most importantly, cowpea, mung bean, and tepary bean have an indeterminate growth habit -- at least partially -- so that more than one harvest cutting is needed. For research staff to sub-sample a plot repeatedly is not practical,**
- **Groundnut plots do not require repeated sampling. However, these plots are small, and grain yield is more easily measured if farmers harvest whole trial plots.**

A3.5.2 Systematic Quadrat Sub-Sampling for Legume Leaf Spinach

Systematic quadrat sub-sampling is used for measuring leaf spinach yield for crops such as cowpea. The procedure is as follows:

- ***Sub-Sampling*. The sub-sampling pattern is similar to that for sorghum and millet (see Section A3.4.1).**
- ***Data and Sample Collection*. In each sub-sample, the number of plants are counted and their leaves are harvested. Take all the leaves to measure the potential harvest. Alternatively, consult with the farmer and choose the intensity of defoliation that is typical. Bulk or combine the sub-samples from each plot.**
- ***Prepare Spinach and Weight*. Ask the farmer to prepare dried spinach and weigh.**

    - **Option 1: Weigh the plot samples while they are still fresh. Take a small sample (0.5 kilograms) from the bulked sample, Give the rest of the bulked material to the farmer to use as he/she pleases. Ask the farmer to prepare the dried spinach from the small sample, Weigh the small samples again when ready as spinach,**
    - **Option 2: Ask the farmer to prepare dried spinach from the bulked sample for each plot, Weigh it when it is ready.**

- **Calculate Yield. Depending on the option, the procedure is:**

- **Option 1:**

  Spinach weight per 100 square metres = [bulked fresh sample (kg) x (small sample dried (kg)/small sample fresh (kg)) x 100] / plot size (square metres)

  For example, if 7.4 kilograms are harvested from a 20m by 10m plot. The 0.5 kilogram small sample, when prepared as spinach, weighs 0.15 kilogram, then:

  Spinach weight per 100 square metres = (7.4 x 100 x (0.15/0.5))/(20 x 10) = 1.11 kg.

- **Option 2:**

  Dried spinach weight per 100 square metres = [(prepared spinach weight (kg) x 100)] / plot size (square metres)

  For example, if 0.95 kilogram spinach is prepared from leaf harvested from a 15m by 12m plot, then:

  Dried spinach weight per 100 square metres = (0.95 x 100)/(15 x 12) = 0.53 kg.

Note: Because leaf sampling might affect grain yield, the researcher should either harvest leaf samples on parts of the plot where grain yield will not be measured or harvest leaf samples equally on all treatments of the legume trial. If leaf sampling is only on some treatments, the others will be favoured, and this might bias and invalidate the grain legume yield comparison of the trial.

A3.5.3 Whole-Plot Harvest for Legume Grain.

- **Whole-Plot Harvest Procedure. Whole-plot harvest for legumes is similar to that for sorghum and millet where farmers harvest the grain (see Section A3.4.2).**
- **Cuttings. The indeterminacy of their growth will require more than one cutting to measure grain yield for cowpea, mung bean, and tepary bean. There are two approaches to dealing with cuttings:**
    - **Option 1: Each cutting is kept separate, If the researcher wants to compare legume treatments for each cutting, the schedule of harvesting by the farmer and weighing by research staff must be organized well. To compare correctly, farmers should harvest each treatment at each cutting, even if the yield is still small.**
    - **Option 2: The cuttings are combined, For most trials, researchers can bulk the different cuttings to get one yield per plot, Even here, farmers often would**

like to use part of the harvest before the final harvest has been completed. To help the farmers, research staff can organize a schedule of visits to check the harvesting procedure and weigh grain harvests to that date.

For example, a farmer makes three harvests on each plot of a trial involving cowpeas. For one plot, the harvest yields were 5.2 kg, 3.1 kg, and 0 kg. For a second plot, harvest yields were 0.1 kg, 2.2 kg, and 12.1 kg. Upon careful measurement, FSD staff found the first plot to be 12m by 15.5m and the second plot to be 10.5m by 12.0m.

Grain yield of plot one (kg/plot) = 8.3 kg/plot

When adjusted for actual plot size = (5.2 + 3.1 + 0)/(12 x 15.5) = 0.0446 kg/square metre or = 446 kg/ha

Grain yield of plot two (kg/plot) = 14.4 kg/plot

When adjusted for actual plot size = (0.1 + 2.2 + 12.1)/(10.5 x 12.0) = 1.142 kg/square metre, or= 1,142 kg/ha

A3.5.4 Whole-Plot Harvest for Groundnuts

Groundnut whole-plot harvest is similar to that for sorghum and millet, where farmers harvest the grain in one cutting (see Section A3.4.2). For groundnuts, grain yield for the

shelled (i.e., shells removed) harvest is reported. A shelling percentage estimate is one of the yield quality measures for groundnut.

To obtain the groundnut shelling percentage, a small sample (e.g., 0.5 kilograms) of unshelled nuts that have been dried for shelling is weighed. Then shell and weigh the shelled sample:

Shelling percentage = (100 x weight shelled (kg)) / weight unshelled (kg)

Shelling percentage can be used to convert unshelled harvest weights to estimates of shelled weights. To get an estimate of yield when a farmer has not yet shelled his harvest: weigh the unshelled harvest, weigh a small shelling percentage sub-sample (0.5 kilograms), shell, and then reweigh the shelled sub-sample:

Shelled harvest (kg) = [unshelled harvest (kg) x shelling percentage] / 100

For example, a farmer has 22 kilograms of unshelled nuts. A 0,5 kilogram sample of unshelled nuts weighs 0.24 kilogram after shelling.

Shelling percentage = (100 x 0.24)/0.50) = 48.00

Shelled harvest (kg) = (22 x 48.00)/100 = 10.56 kg

Grain yield for all legumes is calculated in much the same way as for sorghum and millet. Because plots in legume trials are small and the whole-plot harvest method is used, estimates of yield are sensitive to errors such as overlapping treatments. Consequently, it is important to discuss the requirements of a plot trial with farmers, to inspect plots, and to measure accurately plot size and grain harvest when yield estimates are important.

> **Note: For groundnut, when shelled harvest weight is required, it is best to leave the bulk of the harvest in the shell and use the approach described above. This is because groundnuts tend to store better in the shell.**

A3.5.5 Method for Fodder Crop Plots

Fodder yield is generally measured by systematic sub-sampling, Most fodder trials are FMFI, with only a few plots on each farm. With farmers doing the work, a whole-plot measurement would be preferred. For economic and farmer assessments, larger plots for fodder production and use studies are required. Because fodder is bulky, weighing the entire harvest will not be practical. For this reason, the systematic quadrat sub-sampling method is used. Points to note about this method are the following:

- **Procedures for fodder are similar to the leaf harvest method in legumes (Section A3.5.2).**
- **Set the schedule for harvest measurement with the farmer, Sub-sampling must be done before the farmer harvests the remainder of the plots.**

- **Time the harvest for each fodder crop to coincide with the stage of growth when the nutritive value is optimal.**
- **Cut the sub-samples and immediately carry them to a safe point outside the plot. Sub samples from one plot can be bulked together and weighed, This is a fresh weight. Fodder yield should be reported as dry weight. Spread out the bulked harvest samples for drying. Note that the recommendation for standard fodder production is to allow cut hay to dry to some extent in place. This reduces the weight and burden in transporting. Sub-samples are not heavy and removing them to a safe drying point lowers the risk of accidental loss.**
- **For precise estimates of fodder dry matter yield, research staff need to weigh a harvested sample at one-week intervals beginning about two weeks after the sample is harvested. The exact beginning time is dependent on the weather conditions being conducive for drying, To manage this work, only a representative portion of each bulked sample harvested from the field is separated and weighed. This new drying sub-sample can be put in a large burlap bag and hung to dry, A label on the bag can be used to record dates and weights. Reweigh the drying sub-sample a week later, If the weight is less than that of the previous weight, the sub-sample is still drying. Repeat the weighing until each drying sub-sample weight is constant. Use the constant weight as the dry weight of fodder in the sub-sample.**
- **Calculate dry matter (DM) yield as follows:**

  Proportion dry matter = sample dry weight (kg)/sample fresh weight (kg).

Fodder (kg DM)/harvest sample = bulked sample (kg fresh) x proportion dry matter,

Plot fodder yield (kg DM/plot) = [(fodder (kg DM) x plot size (sq. metres))] / sample size (square metres)

Fodder yield per hectare (kg DM/ha) = [(plot fodder Yield (kg DM/plot) x 10,000)] / plot size (square metres)

For example, 10 quadrat sub-samples (2m x 2m) are harvested from a plot measuring 30m by 30m. The bulked fresh weight of the samples is 42 kilograms. A drying sub sample, weighing 5 kilograms, is dried to a steady weight of 1,2 kilograms,

Proportion dry matter = 1,2/5 = 0,24

Fodder (kg DM)/harvest sample = 42 x 0,24 = 10,08 kg DM/harvest sample,

Plot fodder yield (kg DM/plot) = (10.08 x (30 x 30))/(10 x 2 x 2) = 226,8 kg DM/plot

Fodder yield per hectare (kg DM/ha) = (226,8 x 10,000)/(30 x 30) = 2520 kg DM/ha

- **A less precise measure of fodder yield is obtained by following the procedure above**

with one small change, Instead of repeatedly weighing a drying sample, allow the bulked sample to dry for a set period of six weeks or more. After this period, assume the hay is dry, return, and weigh the entire bulked sample. The weight is for the harvest sample? that is, kilograms of dry matter/harvest sample,

Note: According to research experience, fodder plots are seldom harvested at the optimal time, Researchers should be warned, if harvest is delayed much past the optimal stage, senescence and leaf drop will dramatically reduce harvest yield and harvest quality.

A3.6 Yield estimation for mixed cropping

Mixed cropping research covers a range of trials. Trials differ in the type of growth habit and type of yield that is measured. For example, in a sorghum-melon mix study, yield measurement is for grain in sorghum and for vegetative growth in watermelon, In a sorghum-cowpea intercropping trial, measurement is for grain in both crops,

Many mixed cropping trials are designed to collect relatively precise agronomic data under farm conditions. In these cases research staff will measure yield, In the sorghum-melon mix trial, researchers use a systematic quadrat sub-sampling to measure sorghum yield together with an estimate of percent ground cover to measure melon growth, In a row-planted

sorghum-legume intercropping study, measurements are made on selected rows. Yields are measured in a sorghum-legume mixed cropping trial using the whole-plot harvest method for each crop separately in the mix. These mixtures are broadcast seeded,

For example, as in the yield calculation illustration given for systematic quadrat subsampling (Section A.3.4.1), the FSD team finds 8.5 MT sorghum heads/quadrat in the field, 2.2 HR head stems/quadrat, 5.5 GR heads/quadrat, and 3,7 GZ head stems/quadrat. Sorghum plant numbers average 5.8/quadrat. The quadrat is 2m by 2m. Sorghum head samples weigh 0.032 kg./head for MT heads and 0.015 kg./head for HR heads from the threshing floor, As before (Section A3.4.1) assume the weight of the GZ heads is the same as that for the HR heads. In addition, at each quadrat sub-sampling FSD staff estimate watermelon plant ground cover as well as count the number of pigweed plants (*Amaranthus spp.*), a particularly pernicious weed on these fields. For ten quadrat sub-samples, percent ground cover estimates for watermelon are: 0, 0, 85, 55, I 5, 0, 25, 30, 65, and 25. Pigweed plant counts in the same quadrat sub-samples are 2, 4, 1, 2, 3, 0, 0, 1, 9, and 0.

Sorghum plant density (plants/ha.) = 14,500 plants/ha.
The estimated actual sorghum grain crop (kg/ha) = MT + HR + GR = 1203 kg/ha.
The sorghum grain yield lost to uncontrolled animals (kg/ha) = GZ = 139 kg/ha.
The watermelon ground cover (%) = (0+0+85+55+15+0+25+30+65+25)/10 = 30%.
Pigweed plant density = (2+4+1+2+3+0+0+1+9+0)/10 = 2.2 plants/quadrat = 5,500 plants/ha.

From these calculations, it can be concluded:

The intercrop = 14,500 sorghum plants/ha. + 30% watermelon ground cover.
The intercrop yield = 1203 kg. sorghum grain/ha. + 30% watermelon ground cover.
The botanical cover = 14,500 sorghum plants/ha. + 5,500 pigweed plants/ha. + 30% watermelon ground cover

A3.7 Method for estimating whole-farm production and average grain yield

Information on crop production for the whole farm can be used to describe and diagnose needs of households and inter-season variation in production. Average grain yield for the farm gives a baseline value to compare with results of trials. The Single Interview Visit Method is used. The procedure used is as follows:

- **Select farmers to be interviewed following completion of threshing,**
- **At an interview with the farmer -- usually about 30 minutes -- record in kilograms or volume measures the amount of each crop harvested in shelled/threshed terms.**
- **Ask the farmer to point out the land that he or she has cultivated this season,**
- **Prepare a sketch of the cultivated part of the field,**
- **Measure all sides of the cultivated land with a measuring wheel, If the cultivated block has an irregular shape, divide the sketch into rectangular blocks, as large as possible.**

Measure the sides of these blocks.

- **Calculate the land area cultivated as follows:**

  Area cultivated (square metres) = average length (metres) x average width (metres) for block of land that is cultivated.

  If the block is irregular in shape, use the average of opposite sides as the approximate average length and width.

  Cultivated land (ha) = area cultivated (sq. m)/10,000

- **Calculate production as follows:**

  Farm grain production (kg threshed/shelled) = sum of weights (kg threshed/shelled) for grain crops harvested by the farmer.

  Note the following additional points:

  - **The above formula implies adding production of sorghum and millet and legume crops. Although this is not strictly correct to do, it is probably not so serious an error, because the bulk of the production is sorghum.**
  - **Because farmers express production in volume units, the following conversions may be helpful:**

-- Standard grain bag holds 70 kilograms of grain.
-- Standard 20 litre bucket holds 14.2 kilograms of grain.

- **Calculate the yield as follows:**

  Grain yield (kg threshed/shelled per hectare) = farm grain production (kp threshed/shelled) / land cultivated (ha)

- **Calculate the yield for one crop (crop A) as follows:**

Use the production (kg threshed/shelled of crop A) of crop A from interview with farmer and identify and measure the area planted to crop A.

Yield of crop A (kg threshed/shelled crop A per hectare) = farm production of crop A (kg threshed/shelled) / land cultivated with crop A (ha)

This type of interview can be quick and surprisingly accurate. Measuring the field takes more time than the interview but does not require the farmer to be present, The interview is useful to estimate wholefarm production, not individual plot yield. The method works well in estimating grain production of sorghum and millet, legumes, and so forth, but is less accurate for melon and spinach crop yields. Researchers do not need to notify a farmer before the interview visit, but advanced notification is preferable. The interview obviously must follow completion of threshing and shelling.

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