LIVESTOCK
in mixed farming systems

RESEARCH METHODS AND PRIORITIES

International Livestock Center for Africa,
and
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"LIVESTOCK IN MIXED FARMING SYSTEMS: RESEARCH METHODOLOGIES AND PRIORITIES"

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INTRODUCTION

The livestock component of small farms remains a topic of great concern, not only to ILCA but to farming systems researchers and practitioners throughout the world. In the context of a systems approach to agricultural research and extension, the livestock component of small farms has until recently been somewhat neglected, or left out of the movement altogether. In part this seems to be due to a number of perceptions: the complexity of the animal situation; the traditionalism of animal researchers; the multiple nature of livestock use; the perceived dominance of the importance of crops; and the greater difficulty of on-farm research with animals as compared with crops.

Soon after the Farming Systems Support Project (FSSP) was organized by the University of Florida staff, a Livestock Task Force was appointed to bring together the facts on the importance of livestock in mixed crop/livestock farming systems. The Task Force was charged with reporting on the state of the knowledge relative to on-farm and on-station farming systems research with an animal component, and to assess the needs that should be addressed in future research activities within the farming systems research context. One of the motives for formulating the Task Force was to improve the understanding of the livestock component of limited resource farms and to stimulate consideration if not inclusion of livestock in the systems approach.

Among a number of recommendations emanating from the Livestock Task Force, one addressed the need for regional workshops that would bring together researchers and practitioners to share their experiences with research methodologies and techniques being used to conduct on-station and on-farm trials involving livestock. The workshops were to be

interdisciplinary, including scientists from different disciplines such as animal nutrition, forage and crop agronomy, agricultural economics, rural sociology, anthropology and veterinary science. The common ground for workshop participants would be experience in mixed farming systems including a livestock component.

"Livestock in Mixed Farming Systems: Research Methods and Priorities" is the second in a series of workshops that the Farming Systems Support Project has promoted to address these various concerns. This workshop was a collaborative effort between the FSSP and ILCA, whose hosting, participation and contribution are gratefully acknowledged.

Objectives of the workshop were to present, discuss and evaluate research methods and design techniques used in on-farm and on-station trials in terms of their usefulness and application to farming systems research in crop/livestock systems. Participants were expected to identify major constraints in such mixed farming systems and place priorities on them according to their potential economic importance and amenability to research. In addition, participants were asked to begin to develop guidelines and recommendations for conducting research on livestock in farming systems that would be useful to project planners, implementors and evaluators associated with national research programs, universities, international agricultural research centers and bilateral projects.

It is hoped that these proceedings will contribute in a meaningful way to the continuing evolution of research priorities and the nature of the research thrust with livestock in mixed farming systems.

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THE ILCA/NLPU ON-FARM ALLEY FARMING PROJECT: CONSIDERATIONS ON DATA COLLECTION AND EVALUATION

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INTRODUCTION

The prime objective of agricultural research can be seen as the improvement of production inputs and technologies for the increased production of food and other agricultural products. It is therefore essential that the results of agricultural research get to the farmer who is the ultimate user of the improved technology. This being so, it is equally essential that the socio-cultural environment of the farmer is taken into account in the development of technologies, to ensure that the end-product of research is feasible and viable under farmer conditions.

This question of feasibility and viability under farmer conditions has often been cited or inferred as the main reason for moving research from station to farmers' farms (Kirkby et al, 1981; Steiner, 1982). On-farm research (OFR), is thus seen as serving an extremely important role in translating promising experiment station results into practically relevant and economically sound recommendations for farmers (Stoop, 1982).

Several types of OFR can be distinguished on the basis of a number of factors, two of which are (i) the level of farmer involvement and (ii) the complexity of the trial. These two factors together influence the type of data that can be obtained from OFR. A distinction should therefore be made between OFR designed specifically for the provision of on-farm data on biological and technical parameters, and those established for the development and assessment of the relevance and acceptability of proposed interventions for the farmer.

This latter type of OFR, which has been described as pre-extension OFR (Stoop, 1982) has its major emphasis in the farmers' maximum control

and responsibility in the interventions being tested. Use is made of extension methodologies to gain the required farmer understanding and involvement and evaluation is through assessment of farmer's reactions and responses, rather than through precise measurements in specific parameters. An example of this type of OFR is the on-farm alley farming research of the International Livestock Center for Africa (ILCA), at Ibadan, Nigeria.

ILCA's Alley Farming Package

The Humid Zone Programme of ILCA, based in Ibadan, Nigeria, has, since 1980, been working on the development of an integrated production system for the improvement of crop and small ruminant production in the humid tropics. The system, alley farming, is based on the alley cropping concept earlier developed by the International Institute of Tropical Agriculture (IITA) and is the major component in ILCA's intervention in the farming systems of the humid zone. In alley farming, food crops are grown between alleys formed by rows of fast growing leguminous browse species which are pruned frequently to prevent shading of the food crops. Being legumes, these trees are capable of fixing nitrogen as well as siphoning soil nutrients from deeper layers of soil and releasing them to the top soil through mulching of their nitrogen-rich foliage. The prunings can also be used as feed for small ruminant. Through alley farming therefore soil fertility is maintained to allow for continuous arable crop production at sustained yield levels, and small ruminants production is improved through availability of high-protein fodder.

A second component of the ILCA intervention is the annual vaccination of small ruminants against Pestes des Petits Ruminants (PPR) a viral disease responsible for major mortalities in the small ruminant stock. The disease strikes in epidemic levels and whole flocks may be lost as a result of its occurence. ILCA's research has sh[illegible] PPR can be prevented by annual vaccinations of Tissue Culture [illegible]rpest vaccine (TCRV). In village level (on-farm) trials to test t[illegible] effectiveness of the vaccine, mortalities were reduced by over 70% with vaccination

(ILCA, 1983). These two components (alley farming and TCRV vaccination) together address the major constraints to small ruminant production in the zone - disease and feed - and are seen as having high potential for improvement of small ruminant production without major additions to current inputs.

On-farm Alley Farming Research

The development and testing of ILCA's alley farming intervention is carried out both on-station and on-farm. Figure 1 gives the evolution of ILCA's on-farm alley farming research from 1980 (with a single farmer) to its culmination in a pilot research/development project (involving over 60 farmers) in 1984. Direct researcher involvement in the establishment and management of these trials has changed markedly from very high in the initial years to an almost zero involvement in the pilot project. It is argued that such zero involvement is necessary to enable an accurate assessment of farmer response to a new technology prior to its incorporation in a national development programme.

The Pilot Project

The pilot project was initiated in 1983 by the Nigerian Livestock Project Unit (NLPU), a livestock development agency under the Nigerian Ministry of Agriculture and Natural Resources. The project is based largely on ILCA's small ruminant improvement package (SRIP) which has two components - (i) establishment of leguminious fodder trees (alley farming) and (ii) annual vaccinations of sheep and goats against PPR.

The objective of the project was to test the relevance, and acceptability of the alley farming intervention and assess its potential for adoption and spread amongst small scale farmers in the humid zone of southwest Nigeria.

Owu-Ile and Iwo-Ate, two adjacent villages in the Ejigbo Local Government Area of Oyo State were selected for the project. These

villages are just about 2 km apart, and together have about 500 permanently resident adults living in 201 houses (Okali, 1984). The criteria for selection of these villages were active arable crop farming and interest in small ruminant production.

Background methodologies and different kinds of activities carried out in this project are described by Atta-Krah (1985) and are therefore not detailed in this paper. These activities included village meetings, farm tours, and demonstrations, on principles and practices of alley farming. Leguminous tree seed for the project was supplied free of charge by ILCA. Farmers receiving seed were required to establish alley farms on one of their farm lands. The maximum size suggested for an alley farm was 0.3 ha per farmer. On average, small-scale farmers in the area cultivate 3-6 fields per farmer with a total area of about 2 ha. Only one of a farmer's fields and in some cases only a portion of one field is used for the establishment of the alley farm.

All but four of the 67 farmers receiving tree seeds from ILCA planted alley farms. Planting was done entirely by the farmers with no supervision nor enforced uniformity practises amongst the various farmers.

In the following sections of this paper, monitoring and evaluation issues in the ILCA/NLPU pilot alley farming project will be reviewed against a background of unlimited farmer control in the establishment and management of alley farms.

PROBLEMS OF DATA COLLECTION AND ANALYSIS

In order to fully appreciate the data collection and analysis issues in this type of OFR, it is important to realise that farms under study are actual farmers' farms in which farmers have full control, ownership and responsibility. These are not "research-managed" research plots in farmers' farms.

It must also be borne in mind that the major objective of this research

approach is the development and assessment of the acceptability of an intervention to the farmer. Assessment of the system, whether on biological, economic or social grounds, is therefore, best made by taking the farmer's own view point into consideration. This is because a farmer's decision to either adopt or abandon a tested intervention is more likely to be based on his own personal experiences with the system rather than on the "potential optimum benefits" that may be claimed for the system.

In this type of OFR, as a result of the usually large and fluctuating number of farmers participating, as well as the absolute control enjoyed by the farmers in the management of the trials, it is often difficult to obtain realistic quantitative productivity data. This is because such operations as weeding, tree pruning and crop harvesting are done by farmers on an ad hoc basis, in most cases in the absence of the researcher. The only information that can be recorded in such instances is whether or not a particular activity was carried out on a particular farm, rather than the exact time and quantities involved in the various activities. For this reason, it is necessary to keep such measurements to a minimum, putting greater emphasis on the qualitative assessments, and using adoption and dropout analysis as a reflection of the workability of the system.

Some quantitative data in fixed parameters such as farm size, tree spacing etc. could be collected to provide information for the development of specific case studies or to establish the degree of variability that exists in specified characters. Examples of this type of data from the pilot project are shown in Tables 1 and 2, for farm size, and tree intra-row spacing. Table 1 shows that when given the option, farmers testing a new intervention will prefer to do it on a small- rather than large-scale. Only about 15% of farmers in both villages established alley farms up to the 0.3 ha recommended by ILCA as the starting hecterage. Table 2 also shows that trees in most farms were established with within-row spacings of 40-50 cm, as against the 25 cm spacing recommended by ILCA. Most farmers explained that it was difficult sowing at the close spacings, and even more difficult

maintaining the closely-spaced seedlings under farm conditions.

As a result of the immense and complex web of variabilities arising from the experimental design (or lack of it) is is often difficult to make direct comparisons between farms on the basis of any single factor. The relevance of these variability issues in the pilot alley farming project are discussed under the various headings:

Soil Variability

The decision as to which of a farmer's farm lands should be used for alley farming is made entirely by the farmer. While some farmers planted trees on reasonably 'new' and fertile land, others chose to plant on 'old' depleted land which was due for fallow. There are situations where the land used was so heavily depleted that even cassava could not grow satisfactorily. Under such a range of soil fertility conditions comparisons between farms on the basis of other characters can be misleading.

Variability in Cropping Patterns and Rotations

ILCA did suggest an establishment crop of maize (at least for the first crop season in the trees' establishment) but farmers were free to plant whatever crop they preferred (see Table 3). This was in line with the philosophy of minimum interference in farmers' decisions with respect to the establishment of the alley farms.

Consequently alley farms were established with a variety of crops - maize, cassava, yam, cocoyam, pepper and melon, usually in mixed stands of 2 to 5 crops, and in complex relays and rotations. The different mix of crops, in widely different proportions, on various farms makes it impossible to use the alley crops as source of classification of the farms, or to use crop yields as basis of comparison between farms. This issue of crop yields is further complicated by the ad hoc nature by which harvesting is carried out on farms.

Variability in management

Perhaps the most important source of variability in this project is that due to management of the farms. Farm operations are carried out independently by the farmers, in most cases, in the absence of the researcher. There is, therefore, immense variability arising from such management practices as land preparation, date of planting, species and spatial arrangements of trees and food crops, crop production and farm maintenance (weeding). Correlations between these various factors and tree and crop yields (if obtainable) are not expected to yield any significant relationship on account of the uncontrolled variability in the various factors.

Problems of Labour Estimation

The question of labour requirement for alley farming is probably best treated as part of a full economic analysis of the system. This could be done through economic modeling, using figures from field surveys and OFR. This paper argues that labour is not a critical issue in the establishment of an alley farm. This question is addressed below under various farm activities so far encountered in the establishment and management of alley farms and considerations are given for the assessment of additional labour demands in alley farming.

a) Land clearing and preparation

In alley farming, the tree hedgerows are established in the farmers' food-crop farms and not by themselves as in intensive fodder tree cultivation systems. Clearing and land preparation costs are therefore irrelevant as all these would have to be done with or without planting of the trees. The situation is the same for other land preparation activities such as ridging and mounding. No specific ridges or mounds are required for the trees; in fact in situations where a farm is unridged, the trees are seeded on the flat. No extra labour is expended in land preparation as a result of converting a farmer's food crop farm into an alley farm.

b) Planting and management

Tree planting and related activities such as thinning and row-filling can be regarded as the first activities which introduce an additional labour input into farm operations. The issue, at stake in this, however, is the magnitude or significance of the extra labour required and the returns, from the farmer's point of view, of that labour. Tree planting to establish alley farms in the humid tropics does not involve nursing of seedlings, digging of holes in the field and transplanting, that is required in the establishment of alley cropping farms in the drier areas (Hoekstra, 1985).

Planting is done by direct seeding of tree seeds along every fourth or fifth prepared ridge which would be 4 or 5 metres apart. In all situations where farmers have established alley farms, planting was done by the farmers themselves, usually aided by their children or some other members of the family. In no case was labour hired for the purpose, as is commonly done for land clearing, ridging, and preparation of mounds.

Even though family labour for tree planting represents a cost, (to the farmer?) this is believed to be minimal and not sufficient to constitute a limitation to the farmer in establishing an alley farm. Furthermore, in all cases, the trees were seeded only after the farmer had completed the planting of his food crops, thus minimizing a possible conflict with critical planting time.

Weeding represents the major management requirement in the establishment of the trees. This is especially critical in the first three months of seedling growth. In some cases, however, no special weeding is done for the trees during this period. They benefit from routine weedings carried out for the food crops. It is recognized that a farmer who is either not serious or commited enough to keep the food crops in his farm weeded will not find time to weed and maintain the trees. In such situations survivability is low and establishment may be poor.

During the dry season, and also in situations where a farmer's alley farm is carrying an old stand of cassava, farms are usually left unweeded. It has been observed that some farmers make deliberate efforts to keep the tree rows weeded while not doing general weeding on their farms. This type of weeding represents an additional labour input into farm operations and should be taken into account in the over-all assessment of the economics of the system. This labour demand however occurs outside the peak period.

c) Tree pruning and utilization

The major management activity following the establishment of the trees is the frequent pruning of the trees to prevent shading of the food crops, and for use as mulch or feed for small ruminants. On small farms, such as exist in the pilot project, and given the freedom and control exercised by the farmers in the management of the farms, it is virtually impossible to obtain quantitative data on this regard. Farmers prune the trees when they feel they have to be pruned, or when they need the foliage for mulching or for feeding.

In most situations, except at planting of the food crops, pruning is seldom done in a uniform manner as is the case in on-station alley cropping/farming work. On farms, pruning is a continuous and staggered exercise - this is especially so when foliage is being used both as feed and mulch. It is therefore very difficult under conditions in the pilot project, to establish the relative quantities used as feed and as mulch or the labour input that goes into pruning for either mulch or feed. These quantities can however be estimated from work carried out on station and in controlled researcher-managed on-farm trials.

More of the prunings are used as fodder during the dry season than during the wet (cropping) season, when they are also used as mulch. The extra labour involved in cutting for fodder is suspected to be minimal. This is because the fodder is cut and carried home usually after the day's work on the farm. During the dry season, farmers sometimes go to the farms specifically to cut fodder, but the alternative to this might be a longer walk into the bush to get lower

quality fodder.

MONITORING AND EVALUATION PROCEDURES IN PILOT PROJECT

The objectives of this on-farm research/development project have been met mainly through continuous observations and qualitative assessments and descriptions of what is happening on various farms, and also through the use of short and simple questionnaires for obtaining specific information at different stages of the project. The major tool of this approach has been observation of responses and reactions of the farmer as an indication of his own assessment of the system. The approach has also allowed the identification of problems and opportunities arising out of the exercise of farmer's initiative, and helped establish the remaining programme of research to be done on station.

The alley farms are evaluated periodically by ILCA personnel. In the evaluation each farm is scored on the basis of the establishment of the fodder and their management. The scoring scheme used was as follows:

1 - Poor
2 - Fair
3 - Good
4 - Excellent

Poor establishement, describes farms which have had very low tree survival (less than 25%) with trees showing signs of stunted growth as a result of intense competition with weeds. Farms rated excellent usually have moderate-to-good survival (50-70%) with trees showing satisfactory growth, and the entire farm is generally well maintained.

A summary of the trend of the results is shown in Table 4 and suggests that in general over 50% of the alley farms were well established and managed. An analysis of the adoption/drop out trend (Table 5) gives a good indication of the overall assessment by the farmers, and the potential acceptability of the intervention.

Farmers' assessments, impressions and experiences gained from the

system are further probed by the use of a simple 'post-establishment' questionnaire which was designed to find answers to such questions as:

Why did adopters adopt?

Why did non-adopters not adopt?

Why did abandoning adopters give up?

What use is made of the trees?

What problems were encountered with the system?

What solutions do farmers propose for these problems?

For the purpose of this survey, farmer were classified into 3 categories

1. Farmers with poor/abandoned alley farms
2. Farmers with fair/good alley farms
3. Farmers with excellent alley farms

Ten farmers were randomly sampled from each farmer category for the study. This has enabled some information to be obtained, as to why and how, from the farmer's own point of view, certain farms had excellent establishment while others were poorly established. Such information could then be compared with observations made independently by researchers on the farms. Details of this comparison are, however, not reported in this paper.

Livestock Monitoring

The alley farming package offers two benefits to livestock. These are the vaccination against PPR and the increased availability of high-protein fodder for supplementary feeding. Vaccination is open to all livestock in the village (Atta-Krah, 1985); it should therefore not be considered a treatment factor for the purpose of showing the benefit of vaccination. Response of sheep and goats to vaccination against PPR has been adequately shown in earlier on-farm work set up specifically for that purpose (ILCA,1983).

The benefit of browse supplementation, is also not achieved until after the first year of tree growth. No attempt was therefore made to monitor farmers' animals during this first year. In January 1985, following the commencement of tree pruning and browse feeding by

farmers, a monthly inventory was initiated to enable primary indications of the effect of the alley farming package on flock sizes. For this purpose ten "Alley farming" and ten "non-alley farming" households were randomly selected from each of the two villages. There are three categories of animals in these households: (i) those belonging to alley farmers, (ii) those belonging to non-alley farmers living in "alley farming households" and those belonging to non-alley farmers living in "non-alley farming households". Animals belonging to all individuals in the sampled households are monitored monthly. A summary of the inventories is given in Tables 6 and 7 for sheep and goats respectively. These are only preliminary data and no detailed analyses have as yet been done. The trials have not run long enough to enable productivity and flock size differences to be adequately picked up. A major limitation also in showing animal response to browse feeding under village conditions in the project, has to do with the management system.

The animals are free-roaming, and therefore graze and scavenge together in small village flocks. Under such conditions it is difficult to ensure that browse meant for alley farmers' animals are eaten only by that group. This is even more so as there are animals belonging to both alley and non-alley farmers in most households.

While it may be difficult to detect actual changes between animals of alley and non-alley farmers especially in the short-term, the overall picture of small ruminant development over time will give an indication of whether the alley farming intervention has had some effect in the area as a whole. So far indications are that flock size of alley farmers' goats is increasing (Table 7). It is not yet clear to what extent this is a direct result of alley farming package (reduced mortalities from PPR control, increased productivity from browse feeding) or an indirect effect through renewed interest and increased investment in small ruminants following an improvement in the health and feed situation as a result of alley farming.

SUMMARY AND CONCLUSION

The monitoring methodology and type of data collected in any on-farm trial should be determined from the objectives of the trial as well as other site-specific factors and circumstances. In situations where the major objective is to "measure biological and technical parameters of proposed interventions on farms", adequate researcher control is required to enable reliable quantitative data to be obtained. On the other hand, where socio-cultural compatibility and farmer acceptability of a new intervention is being assessed, as in the case of the pilot project, it is often adequate to rely on adoption analysis as an indication of acceptance of interventions for farmers.

The results obtained so far have been very encouraging with over 60% of farmers who planted alley farms in 1984 actively managing their farms and about 45 new farmers planting alley farms in 1985. What has been seen by some as the major weakness in the approach - i.e. lack of analyzable quantitative data - is in fact its strength, as it has enabled the required involvement and control of the farmer in the project.

Researchers should be aware of the tremendous potencial of qualitative data for measuring the relevance of proposed interventions for farmers. Increased emphasis should be placed on evaluation of farmers' own responses which should be seen as the sum total of all considerations--technical, economic and socio-cultural.

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DISCUSSION

Q. Have you increased productivity and if so, how much and in what sectors? Without these data, how can you approach a ministry or a donor to justify large-scale extension of the project?

A. Farmers would not adopt the practice if it were not more productive. Rate of adoption indicates success and more farmers want to join the program. Indirect measures such as stock numbers on trial farms, indicate higher income. Ministries and donors have been interested and supportive in spite of the lack of this type of data.

Alley farming has a long experimental history which shows it is a profitable innovation. Economic modelling has been done with mixed farm and station parameters; so we are confident that the system has at least a good chance.

ILCA at Ibadan, Nigeria, has converted a group feeding trial with browse supplementation to an individual feeding trial to measure intake more accurately and secure a better estimate of performance. The problems with on-farm trials and the measurement of intake of supplementary feed are far more difficult to overcome.

Comments:

Expanding on the above answers, ILCA is not ignoring an essential element of FSR by supposing that good results in on-station trials are necessarily achieved when a new technology is transferred on-farms. Surely FSR requires a feedback process from on-farm trials to assess the degree of achievement on-farm of the benefits found from on-station work. Where there is a serious discrepancy in achievement, further

research to explain this is necessary.

We have not taken detailed measures of biological productivity on farms with alley cropping, because of the difficulty of taking these measures, and the difficulty of interpretation of necessarily highly variable data. We have taken the rate of adoption of the technique by farmers as an empirical indication of its usefulness and benefit to small farms. We are also monitoring changes in herd sizes of farms who have taken up the technique.

It is agreed that feedback from FSR is necessary in the development of technologies. Not only is this realized through the use of quantitative data, but also through the identification of problems and opportunities arising from on-farm work through participant observation and informed interviews of farmers as well as through the use of simple questionnaires. Much on-station research has been generated this way, all of which enables us to continue to improve and develop the system.

Variability among farms is not reason enough for failing to compile quantitative data for comparisons and measuring trial performance among farms. Farms can be stratified on the basis of the major factors of variability such as soil, climate, firm size, household size, wealth, etc. and comparisons made.

This may be possible for some international projects but not in the case of the project in question. This is because one can do stratification on the basis of only one factor at a time, leaving all the other factors uncontrolled. In situations where farmers have maximum control, the issue is one of a "complex web of variabilities" rather than variability in a particular factor.

In response to a query of obtaining economically valid data from on-farm trials with alley cropping, one can say that researcher managed-farmer executed trials would be performed in collaboration with IITA to obtain answers to some of the points raised in the Question. However, the farmers would be forced, by the trial conditions, to

modify their farming practices, and thus the validity of the results with respect to normal practices of the farmers will remain questionable. The variability of the farms will remain problematical in the absence of the researcher managed trials.

ON-STATION RESEARCH ON DRAUGHT ANIMALS:

AN EXAMPLE FROM NIGER

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INTRODUCTION

Animal traction, an important example of livestock integration into agriculture, is practiced in many African countries. In Kenya, 12 per cent of all cultivated land is ploughed by draught oxen (Eicher and Baker, 1982). In Burkina Faso and in Mali, 20 to 30 per cent of farmers include animal traction in their cultural practices (Muzinger 1982).

Less hard work and a greater productivity are among the incentives which have led the farmers to adopt animal traction (Casse 1965; Hasif 1978). Currently, the increasing cost of fossil fuel encourages draught technology development to the detriment of motorized equipment.

In spite of the growing importance of animal traction, knowledge on the specific needs of draught animals is much more limited than that of livestock raised for its meat and dairy production (Smith 1981).

Research at the station has, however, covered many related subjects[1], such as:

- improvement of the yoke and harness
- development of ploughing instruments adapted to animal traction
- development of cultural practices using draught power
- studies on power output of different draught animals
- breeding of hybrid animals adapted to traction
- nutritional needs of animals during different work load and working periods
- effects of work on reproduction and lactation capacities

On-farm research has concentrated on testing results from station

studies and examining the socio-economic impact of animal traction introduced to small farms.

CIPEA-NIGER ANIMAL TRACTION RESEARCH PROJECT PROGRAM

CIPEA-NIGER program objectives

The CIPEA-Niger Program is part of the FSR teamwork of ICRISAT[2] Sahelian Center in charge of:

(a) studying the role and contribution of livestock in the economy of agro-pastoral farming systems in semi-arid regions of Niger.

(b) research and testing of appropriate technology to increase animal production and the small farmer's income.

Four villages were chosen as study sites in a region where the mean annual rainfall varies between 400 and 600 mm.

Animal Traction Research Project

The goal of the project executed at the experimental station is to determine the most suitable ways to introduce animal traction at the study sites. "Ex ante" analysis of study sites has shown that:

- the Sahelian climatic conditions are characterised by unpredictable rainfalls
- soils are predominantly sandy
- millet is the main crop
- draught power is not used much and the high cost of agricultural tools and animals is a major obstacle to its introduction

Methodology

Methodology consists of comparing manual cultural practices to different types of animal draught practices used in the cultivation of

millet (harrowing, plowing, ridging). Various types of hitch (e.g. one ox, one donkey, a team of cows or oxen) and of agricultural tools (hoe-sine, plough, canadian cultivator) are tested. A profitability study of the vaious practices is also planned.

Preliminary results

An initial trial done in 1984 (a low rainfall period of only 260 mm) has shown that the use of donkey and a pair of oxen in soil preparation saved repectively 14 and 40-50% of the time needed to prepare the soil manually (Table 1). As for the overall work time, only ridging showed a significant economy of time, 26% of the total time used for the manual practice (Table 2). The low rainfall affected the yields which showed no significant difference between the various cultural practices.

APPROACH METHODOLOGY AND CONSTRAINTS TO ON-STATION RESEARCH ON ANIMAL TRACTION

The on-station research seeks to evaluate intervention packages (team hitch - tools - cultural techniques) which must then be tested, in the field for the most part, and later disseminated through extension.

The approach methodology consists, therefore, of the following:

1. defining research priorities taking into account the needs of target groups and national policies in order to facilitate the adoption of the new technologies.

Those research priorities must also include the study of the nutritional needs of the animals in question. Graph 1, which traces the curves of draught oxen mean weight changes, indicates that, at the end of the dry season and during plowing, the animals show a considerable weight loss reducing their performance.

The study of the different work capacities of the various teams and the

research on their specific needs, if not interfering in the farm work, should be intensified.

2. establishing research protocols keeping in mind the food resources and the animals available on the small farms.

3. experimentation

4. economic analysis of data, knowing that the small farmer, the ultimate user of the developed technology, perceives all technologies in terms of profit.

On-station research can also have constraints:

1. of a financial nature: particularly for some national institutions which, for lack of funds, are forced to stop their research projects.

2. involving human nature: research on animal traction is still fragmentary because it was initiated by foreign researchers whose contract is usually short term.

3. of a technical nature: it is often difficult to extrapolate the results of research done at the station due to the small size of their experimental units.

CONCLUSION

The importance of the role of animal traction in the agro-pastoral farming systems justifies the research done at the station aimed at developing cultural materials and techniques, breeding and nutrition of draught animals, and evaluation of draught power. The example of the studies undertaken in Niger has attempted to define the modes of introduction of animal traction in a climatically-risky region. However, in a general manner, the definition of on-station research priorities and the establishment of protocols must take into account

the needs of the small farmer and the available resources of the target regions.

FOOTNOTES

1. See FAO 1970; Gryseels 1980; Goe 1983; Monnia 1965; Nourrissat 1965; Smith 1981.

2. International Crops Research Institute for Semi-Arid Tropics

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GRAPH 1. Study of animal traction in small farms in Mali.

Curves of draft oxen means weight changes.

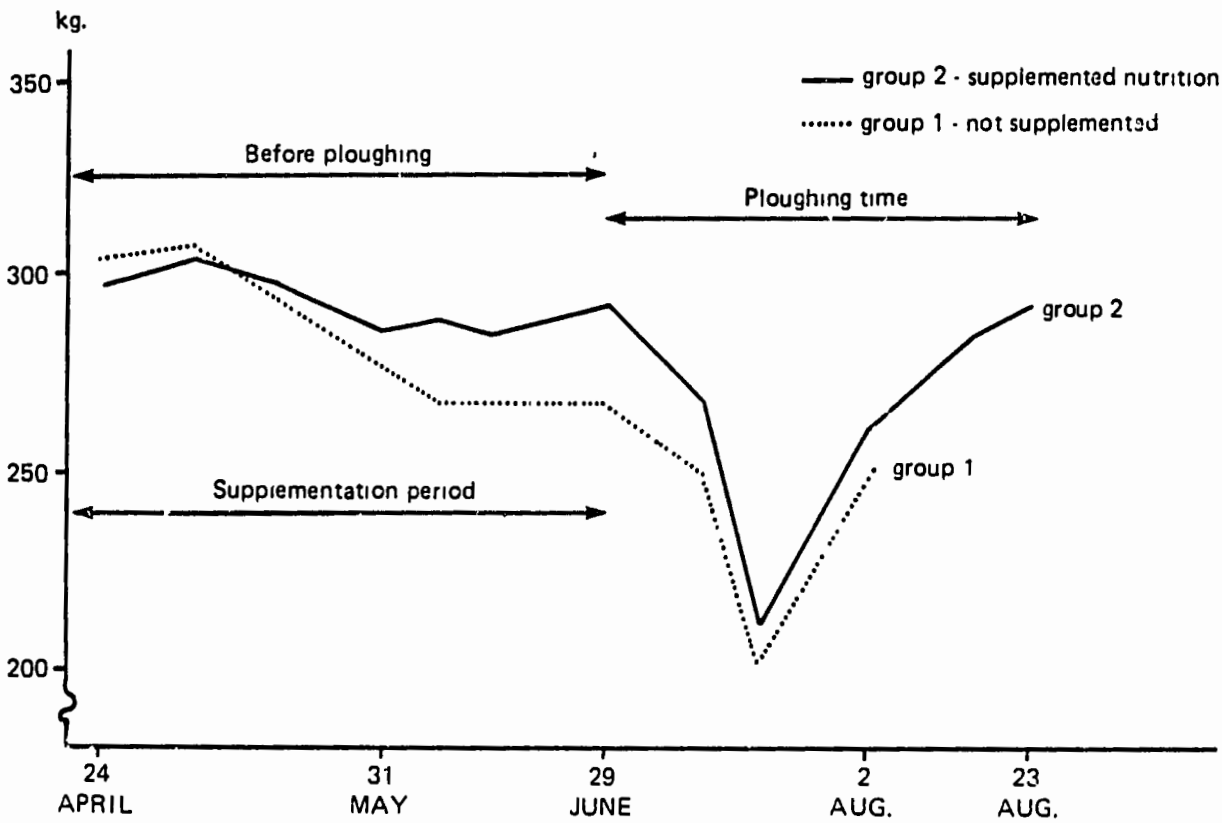

TABLE 1. Time for soil preparation (in manhours and % of time taken in manual preparation.

Type of soil preparation	Working time MH	% of manual time
Manual	28 (6)	100
Harrowing - donkey	25 (9)	14
Harrowing - team of oxen	15** (6)	50
Ploughing - team of oxen	14** (2)	46
Ridging - team of oxen	16** (3)	42

- (~) standard deviation
- ** P = 0.01
- tests of variance between draft time and manual time: degree of probability.

TABLE 2. Types of soil preparation.

Practices	Operations	Power Source	Working time MH	% of manual Time
[illegible]	harrowing	man	152 (12)	100
P2	harrowing	donkey	138** (14)	90.7
P3	harrowing	2 oxen	144 (22)	94.7
P4	surface plowing	2 oxen	143 (18)	94.0
P5	ridging	2 oxen	113*** (14)	74.3

- (~) standard devation
- ** P = 0.05
- *** P = 0.01

DIFFICULTIES IN EVALUATING ON-FARM EXPERIMENTS WITH LIVESTOCK: EXAMPLES FROM THE ETHIOPIAN HIGHLANDS

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INTRODUCTION

The basic objective of ILCA's Highlands Programme is to study ways and means of improving the overall productivity of mixed smallholder farms by increasing the technical and economic efficiency of livestock enterprises. Particular emphasis is given to enhancing the complementarity of the livestock and crop components in these mixed farming systems (Gryseels and Anderson, 1983a).

Although to date field research has been undertaken only in the Ethiopian highlands, it is anticipated that the results and experience of this research will, in many cases, have direct relevance to other highland smallholder situations in sub-Saharan Africa. In addition to research undertaken at ILCA's headquarters in Addis Ababa, field activities of the Highlands Programme focus on two study areas: around Debre Zeit, located 50 km south of Addis Ababa at an altitude of 1850 m, and around Debre Berhan, 120 km northeast of Addis Ababa at an altitude of 2850 m.

The programme has adopted the farming systems approach to research. This integrated and problem-oriented approach stresses on-farm technology testing and approval, complemented by relevant station research on individual components in cases where greater experimental control is advantageous (Gryseels et al., 1984). The evaluation of technology is on a whole-farm basis, though farmer-managed tests are a crucial part of the approach.

A major part of the activities of the Highlands Programme are conducted outside the station. Baseline surveys in each of the study areas have been followed by continuing studies of 'control' farmers in the traditional farming system of the local Peasants Association (PA)

surrounding both ILCA sites.

These studies of the traditional farming system have been complemented by on-farm trials of various innovations. On-farm trials have been initiated on a range of topics, including the use of crossbred cows and forages for smallholder dairy production, the use of single oxen rather than the conventional pair for land cultivation, the construction of ponds and dams using oxen-drawn metal scoops, and the use of crossbred cows as draught animals in addition to their primary role as milk producers.

These on-farm trials are important to assess the feasibility of the new or improved technology under farmers conditions, and in monitoring and evaluating adoption problems. Because of the special nature of livestock enterprises, such on-farm trials do not give statistically adequate information to assess the longer-term impact of new technology on livestock productivity. As a result, on-farm research with livestock cannot be a substitute for station-based research. This paper illustrates this problem using results of on-farm research at Debre Zeit as a case study.

SPECIAL CONSIDERATIONS WITH ANIMALS IN ON-FARM EXPERIMENTATION

Various authors (Bernsten, 1982; Gryseels, 1983; de Haan, 1983; Bernsten et al., 1983; Zandstra 1983 and Zandstra, 1985) have described the difficulties in conducting and evaluating on-farm livestock research. These problem areas are summarized in Table 1.

Bernsten et al. (1983) list them as problems related to the following:

Mobility of Livestock

Mobility makes it difficult to describe environment-livestock interactions, to measure and control factors not included as treatments, and to organize data collections.

Life Cycle Duration

While grain crops typically mature in a few months, the reproductive cycle of ruminant livestock extends over at least a year. This increases the timeframe and cost of experimentation, as well as the risk that experimental animals may die or be sold before the trial is completed.

Life Cycle Synchronization

Crops of similar varieties are planted and harvested more or less at the same time. Animal production, however, is not synchronized and occurs at different times and intervals. This makes it difficult to find animals of the same production categories and in the same production phase.

Multiple Outputs

Animals produce several outputs of economic value. These outputs include milk, meat, manure, draught power and hides. Many of these animal outputs are intermediate products and are used as inputs in the crop enterprise. This makes it difficult to measure the impact of treatments, to evaluate the economic impact of an intervention and to assess the constraints in the farming system.

Non-market Inputs and Outputs

Smallholder livestock production systems depend on inputs such as children, crop residues, semen, and water which are difficult to value, and produce outputs such as draught power and manure for which there is no ready market. The value of other functions of animals such as capital accumulation, risk management and ceremonial functions are difficult to measure.

Size of Experimental Unit

Smallholder farmers have only a few large ruminants. Exposing these to trials and treatments in the research exposes the producer to substantial risks. Moreover, a large number of farmers will have to participate in trials in order to achieve statistical significance. This increases the cost of on-farm experimentation substantially. Also, farm comparisons with a control group are rarely possible and the researcher needs to resort to cross-farm comparisons.

Producer Attitudes

Livestock are subject to various religious and cultural taboos which makes it difficult to cull, castrate and earmark them.

Management Variability

The management of livestock includes a large number of critical decisions (feeding, watering, milking, breeding, animal health control, etc.) which need to be made regularly, often daily, over a long production cycle. The variability of this management makes it difficult to attribute the effects of certain treatments given the number of experimental units.

Number of Observation Units

Livestock performance is measured as production per animal, and as small farms tend to have only few animals, the statistical variability of performance within treatment groups tends to be large.

Other factors that could be added to this classification are problems related to:

Ownership of Animals

Many animals are inherited, or managed by people other than the owner in a benefit-sharing agreement. This makes individual decisions related to management difficult.

Resource Attributes

Livestock will often graze on land which is communally owned. This tenure problem severely limits the scope of on-farm pasture experiments.

Target Audience

Livestock are managed by more than one person. The role of women and children is particularly important. This complicates the organisation of management of livestock experimentation.

ON-FARM LIVESTOCK RESEARCH AT DEBRE ZEIT

ILCA's initial field research activities in the Ethiopian highlands centred on a 160 ha site in the Ada Wereda of the Yerer Kereyu Awradja near Debre Zeit, 50 km south of Addis Abeba. The area was considered representative of the medium altitude highlands of Ethiopia. A baseline survey of the Ada Wereda was carried out first, in order to provide a basic understanding of the traditional farming system. This baseline survey was complemented by socio-economic studies in the local Peasants Associations surrounding the ILCA site. Results of these studies are summarized in T. Makonnen and G. Assamenew (1978) and Gryseels and Anderson (1983).[1]

Around Debre Zeit, smallholder mixed farming is the dominant mode of production. Details of this cultivation system can be found in Gryseels and Anderson (1983) and Gryseels et al. (1984). Most farm produce is kept for family subsistence consumption and average cash

incomes are between US$ 150-200 per annum. Rainfall averages 845 mm of which 70% falls in the main rainy season between July and September. Farm sizes averaged 2.5 ha around 1980 but with increasing population pressures have since been declining and now average around 2 ha of cropland. The area is intensively cultivated and virtually no arable land is left fallow. Teff (Eragrostis teff) is the principal cereal grown. About two-thirds of the cultivated land is sown to cereals, with most of the remainder sown to pulses. The main crops grown are teff, wheat, barley, maize, sorghum, horse beans, chick peas and field peas. Net grain yields (after deducting seed) average around 800 kg/ha.

Most farmers own livestock and a typical farm inventory includes two oxen, a cow and young stock, a few sheep or goats and a donkey. Cattle are kept mainly as a source of draught power and for manure which is dried and used as fuel. Productivity of all livestock is low, reflecting an underexploited genetic resource and generally inadequate nutrition, particularly during the extended dry season of up to seven months each year. For example, milk offtake from indigenous cows kept under traditional management rarely exceeds 400 kg.

Major constraints limiting smallholder productivity around Debre Zeit are low soil fertility on slopes; poor drainage of fertile bottomlands, limiting grain production; limited wood supplies, necessitating use of manure as fuel; dry season feed shortages, causing production losses in livestock; low cash incomes, limiting investment; variation in work oxen ownership, causing differences in area cultivated, cropping patterns, and income; and marketing constraints for livestock products.

Station research at Debre Zeit therefore deals with topics related to: draught animal utilisation; forage, legume and crop agronomy; soil fertility; dairy technology; animal nutrition; and valley bottom development through cheap methods of surface water control.

On-farm trials at Debre Zeit focus on improved dairy husbandry through the introduction of crossbred cows and forages, the use of these cows as draught animals in addition to their role as milk producers, and the use of oxen as singles rather than in pairs for land cultivation. The results of these trials follow.

Introduction of Crossbred Cows and Forages for Dairy Production

Thirty-four families were originally resident on the land granted by the Ethiopian Government to ILCA at Debre Zeit. Of these, 18 volunteering farmers were the initial focus of the on-farm trial of crossbred dairy cows which started in 1978. Each farmer bought a crossbred (Friesian x Boran) dairy cow, cultivated an average 2.5 ha of arable land, and had access to a 30 ha communal pasture. The crossbred cow was to be fed mainly on a special purpose forage mixture of oats (Avena sativa) and vetch (Vicia Dasycarpa). The productivity of the farming system was to be further improved by the use of improved seed and chemical fertilizer on subsistence food crops, and generally improved farm management.

The 18 'test' farmers adopted this dairy husbandry package at their own expense and risk. They themselves could decide whether or not to accept the technology and ILCA's management recommendations. In return for agreeing to participate in the research programme, these farmers received long-term (five years) credits for the purchase of the cow (which cost US$300) and the construction of a shed. Extension inputs were provided by ILCA until early 1981 and then gradually reduced to correspond to conditions which would normally apply in a development project.

The performance of these test farmers was monitored by ILCA through regular visits by a 12th grade enumerator. Initially these visits were weekly, but after 1981 they were reduced to once every two weeks to avoid excessive ILCA influence. Literate farmers participated in a self-recording scheme for milk production. Originally it was planned to have over 30 dairy test farmers, but this target was not achieved

because insufficient crossbred cows were available from the government ranches.

During 1981, the ILCA programme was instead expanded with 13 additional farmers who bought their crossbred cows through other channels, mainly the Extension and Project Implementation Division (EPID) of the Ministry of Agriculture. These farmers are referred to in this paper as EPID farmers. Their farms are located within a 20 km radius of the ILCA station.

For breeding purposes, ILCA relied initially on the artificial insemination (AI) service of the Ethiopian Government. When this proved unsatisfactory, ILCA purchased a purebred Friesian bull for the station needs, and to serve the cows of the test farmers. As a result of using a purebred Friesian bull, the calves had 75% exotic blood. Although only few smallholder farmers have the feed resources and management ability to handle 75% crossbreds, the available half bred bulls lacked libido and proved unsuitable for breeding purposes.
There were significant differences in the results obtained before 1981, when ILCA was still providing extension services (weekly visit of an extension officer, supply of forage seeds and feed concentrates, animal health care, etc.) and when ILCA stopped providing these services, limiting its activities to monitoring. There were also significant differences in the performance of 'test' and EPID farmers (because of ILCA vicinity) and between 50% and 75% crosses. The managerial factor was of overwhelming importance in performance evaluation of the crosses.[2]

Results on average milk production are indicated in Table 4. EPID farm results monitored from 1981 only refer to the fourth to seventh lactation as previous data were not available. This illustrates the problem of synchronisation of experiments. Average values of lactation yields and lengths for crossbred cows of 'test' farms before and after 1981 are indicated in Table 5. The differences in productivity are due mostly to a reduction in the use of feed concentrate and to increasing age of the cows.

Milk Yields

From 1978 to 1984, overall average milk production for all farms per lactation was 1969 kg (cv 22%), average production for the first 305 days was 1775 kg (cv 19%) and average adjusted annual milk yield (AAMY) was 1667 kg (cv 23%). An analysis of variance indicates that these differences are caused by differences between test and EPID farms, individual farms, and the number and year of calvings. (Table 2). The differences between 50% and 75% cows can almost be completely explained by year effects. All lactations of 75% cows date indeed of the period after 1981. An analysis of variance of this period did not give indications of significant differences between crosses.[3]

High yields of the first lactation are due to the long lactation period which was caused by the absence of breeding services and the delay in purchasing an ILCA bull. Farmers kept milking until the cow stopped producing milk. Overall average daily milk yield was 5.8 kg (cv 18%) while milk yield per metabolic unit was 20.9 kg (cv 22%).[4]

Lactation Length, Age at First Calving, and Calving Interval

Average lactation length for all cows was 339 days (cv 21%) and the dry period 122 days (cv 79%). The third lactation of test farms was substantially shorter than the first and the second (291 days vs 439 and 319 days). This is due to a shortage of feed concentrates but other factors (forage and pasture production) could have played a role as well. The dry period of 75% crosses was almost twice as long as for 50% crosses, even though there was no significant difference in lactation length. The lack of feed may have caused delays in the post partum oeustrus cycle, but this is only a hypothesis.

Average age at first calving was 968 days for 50% crosses and 1016 for 75% crosses. The CV of age at first calving was generally less than ten percent. On average two services were necessary before successful conception, though there was high variation in this. Around

36% of cows were pregnant after one service while 68% were pregnant after two.

Average calving interval was 460 days (cv 24%). No significant differences were observed between test and EPID farms, between farms, between 50% and 75% crosses, number of calvings or season of calving.

Mortality

Overall calf mortality up to the age of two years, including abortions, was 42% for 75% calves and 53% for 87.5% calves. On test farms abortion was responsible for 21% of mortality: 15% died during the first 30 days of life; 8% between one and three months of age; 21% between 3 and 6 months; 12% between 6 and 12 months; and 23% between one and two years of age. Mortality was slightly higher for male calves than for female calves. Until 1981 average weaning age on test farms was 124 days for female calves who consumed an average of 328 kg of milk, and 88 days for male calves who consumed an average of 328 kg of milk. Calf mortality increased dramatically after 1981.

Birth weights of calves averaged 30 kg for 75% crosses, compared to only 25.5 kg for 87.5% crosses. This difference in birth weights between both crosses was statistically significant at the 0.1% level. Mortality of adult cows was only 12%. The reasons for death are unclear, but liverfluke, skin and tick diseases and diarrhea are common. Since the enumerators were 12th grade students without veterinary expertise, the precise cause of death could not be established.

Seasonal Influence

There is an indirect correlation between rainfall and milk yield. As the rainy season starts, pasture growth is stimulated and feed resources improve dramatically. The peak of milk production is about one month before the peak of the rainy season. Conception increases

dramatically also. Increasing rainfall also increases mortality, probably because of the higher incidence of ticks, insects and parasites. (Table 3)

Impact on Socioeconomic Welfare

Gryseels and Anderson (1983b) have evaluated the introduction of crossbreds on family welfare and found that cash income per farm increased on average by 227%, although large variations were observed. These results deal with the period before 1981, and the results of the later period are presently being analysed.

It was difficult to determine the profitabilty of the dairy enterprise. For example, it is almost impossible to determine the value of a female heifer which is not yet pregnant. The majority of crossbred animals are supplied by the government breeding ranch and as yet there is no free market for them. This also complicates assigning a value to the cow which is sold by the government at a subsidized price.

Other socioeconomic and welfare factors include the following. Forages are grown on arable land and there is an opportunity cost in terms of growing subsistence crops versus forages. This opportunity cost of the land has to be taken into account. Cattle dung is dried and used as a fuel in the household. Although there is a market price for dung, the capacity of the market to absorb supplies is limited.

Most Ethiopians belong to the Coptic Orthodox church which prohibits the consumption of veal. This makes the valuation of male calves difficult. Feed inputs are difficult to value. There is no commercial forage seed production; pastures are communal; straw is a by-product of the crop enterprise; and the supply of feed concentrates is irregular. Health care and breeding services are not available either commercially or from the government, and difficult to value.

Followers of the Ethiopian Orthodox church also observe around 140

fasting days per year, during which the consumption of animal protein is prohibited. This severely limits the marketing of milk during these periods; milk prices will then fluctuate widely. Evaluation of the crossbred cow enterprise is further complicated by its interactions with the crop enterprise. For example, farmers who grow forages replace crops with the lowest gross margin. Mostly these are pulses which make a valuable contribution to soil fertility. Competition for labour between crop and livestock enterprises has also been a constraint.

Discussion

The objectives of the on-farm trial with crossbred cows were to study the productivity of these cows under farm conditions, to appraise smallholder adoption problems and to evaluate the impact on the socio-economic welfare of the farmer and his family. The on-farm trial has clearly indicated that a genetic treatment (through crossbreeding) gives significant effects. There are also significant effects of anotner treatment, i.e. concentrate feeds. A third is that there are major interactions between these two treatments. More statistical work is needed to quantify differences of performance within treatments. Results are confounded and sometimes difficult to interpret. The differences in management are large between the different farmers and it is not easy to attribute the effects of treatment related to fodder, health, watering, housing or general management. For example, feed concentrates have a dramatic impact on milk yields but their supply is irregular. As they are cheap, every farmer will use as much as possible as long as they can obtain them.

Some farmers have easier access to feed concentrates than others and this explains the large variation in their use. Out of 31 farmers, 16 grew forages in 1984, while 15 did not because with rapidly increasing teff prices, they thought it was more profitable to grow cereals than to produce extra milk. The feed problem is accentuated by the fact that most farmers still keep cows of local breed for investment purposes and for supply of oxen.

During the dry season only four farmers watered their cows three times a day; 17 watered two times a day and eight farmers watered once a day. Roughly half the farmers never had health problems with the cow. The other farmers reported only minor health problems. Farmers identified their most important problems as being the lack of feed, breeding (lack of suitable bull) and lack of a market for fluid milk. Out of 28 farmers, 16 let their calves graze on home compound only, 10 grazed calves on the home compound and outside the farm compound, while only two had a zero grazing system. All of these differences in management make it difficult to attribute management effects on production.

The impact of management on the productivity of cows can be further illustrated through ILCA's experience with a cooperative farm unit. A 20 ha cooperative farm was established in 1978 and was mis-managed by 10 farmers nominated by the local PA. A production package similar to the one for dairy test farmers was introduced. It included a dairy enterprise based on 12 Arsi x Friesian crossbred dairy cows and forage production.

Results of this cooperative venture are indicated in Table 6. These results clearly indicate the bottom level of productivity of cows when badly managed. The cooperative farmers had no previous dairy farming experience and lacked motiviation. The venture was discontinued after 1981.

Given the reliance of farms on purchased concentrates, one wonders what the effect would be on milk production and reproductive performance without concentrates, using only a feed regime of grazing and straw . At the moment the supply of concentrates is irregular and insufficient data are available to estimate a production function.

Given the high CV's of the various productivity parameters in the on-farm trial, and the impossibility of attributing the effects of certain management variables, these technical relations are to be

established in on-station research where greater experimental control is possible.

Use of Single Oxen

Ploughing in the Ethiopian highland is traditionally done using paired oxen, but surveys showed that half of the smallholders in the highlands owned fewer than two oxen . During 1983 ILCA developed a single ox yoke and harness, and a modified version of the wooden plough, the Maresha, suitable for use by a single ox of local breed. On-station testing showed that an adequately fed ox could cultivate singly in a day 60% to 70% of the area normally ploughed by a pair.

Field days were organized for local farmers from the Peasant Association around ILCA's research stations. After the field days, farmers were invited to try the adaptation of the traditional method at their own farms, at their own risk and expense. ILCA provided assistance in retraining oxen to work as singles and in teaching the farmers how to modify the plough.

At Debre Zeit more farmers had two or more oxen than the national average but around 25% of the smallholders had fewer than two. The number of oxen owned by farmers at Debre Zeit strongly influences the area cultivated and the cropping pattern. This also affects farm incomes substantially. A farmer owning fewer than two oxen has various ways of overcoming the problem of inadequate draught power.

These ways are described in Gryseels et al. (1984) but generally the farmer can opt for either renting an ox, exchanging his labour for an ox or share his ox with another farmer who also has one ox.

During 1983, 12 Debre Zeit farmers volunteered to try the single ox system. During 1984, twenty-four additional farmers also started ploughing with a single ox, while two farmers of the first year left the trial for reasons not related to the research. Of the 34 farmers who participated in the trial during 1984, 30 were individual farmers

from 3 different Peasant Associations, and four worked in producers' cooperatives.

Results of the 1984 Single Ox Trial

This section focuses on the results of trials involving 30 test farmers during the 1984 cropping season. Results of the previous season are reported in Gryseels et al. (1984).

The average farm size was 2.3 ha (CV 33%) which was virtually all cultivated; pastures were on communal land. Of the 30 farmers, two cultivated less than one ha of land (group I); 6 had between one and 1.9 ha (group II); 17 between two and 2.9 ha (group III); and five had more than three ha (group IV). The number of oxen owned by these farmers was almost proportional to the area cultivated. One farmer had no ox; 12 had one ox; ten had two; and seven had three or more oxen. All farmers used a combination of single and paired oxen for the land cultivation. Of those farmers who only had one or no ox, 60% had a 'minda' (renting) agreement, and 40% a 'Mekanajo' (pairing up with somebody else's ox) arrangement.

This combination of using both paired and single oxen reflects a natural caution about the new technique. Around Debre Zeit, because soils are heavy (black cracking clay-soils, vertisols) and rainfall is essentially unimodal, cultivation for the main cereal crops has to be done within a very limited period. Land preparation on the vertisols begins in mid-June and must be completed by the end of July. It is very difficult for a farmer to finish all the necessary cultivations (five) and planting within that period, because each farmer has to work one or two days each week on communal activities organized by the PA. In addition, religious restrictions limit the available days for field work to two or three per week.

Of the mean holding of 2.3 ha, 0.45 ha (or 20%) had been ploughed with a single ox, while 1.85 ha (80%) was ploughed using the conventional paired oxen. The area cultivated per farm with the one ox system

ranged from 0.1 ha to 1.1 ha with a CV of 62%. Farmers with less land ploughed proportionally more with one ox than larger farmers.

However, in each group the CV remained very high (CV=59% for farmers cultivating less than 1.9 ha, 65% for farmers with between two and 2.9 ha, and 49% for farmers cultivating between three and 3.9 ha).

The area cultivated seemed proportional to ownership of draught oxen and and family size. Farmers cultivating less than 1.9 ha had one ox each and an average family size of 4.7; those cultivating more than three ha had an average of 3.6 oxen and an average family size of seven.

With a single ox it took an average 166 hours to cultivate one ha of land, or 19% more time than the 139 hours required by a pair of oxen.

This is partly explained by the higher fraction of light soil ploughed by single oxen, which, surprisingly, took more time than cultivating the heavy black soil. Table 7 summarizes the results in cultivation time for both single and paired oxen. An analysis of variance has indicated that the differences in cultivation time between single oxen and ox-pairs were statistically significant at the 10% level for the light soil, but that the differences were statistically not significant on the black soil.

The average cultivation depth obtained with single ox ploughing was 12.2 cm on the first pass (11.3 cm on the light and 13.1 cm on the black soil), rising to 15.4 cm on the fourth cultivation (15.3 cm on the light soil and 125.5 cm on the black). The main crops cultivated were teff (59% of the area cultivated), other cereals such as wheat, sorghum and maize (19%), pulses mainly chick peas, rough peas and horse beans (18%) and vegetables (3%). Only 1% of the land was left fallow. There was no significant difference in the cropping pattern of land ploughed by single oxen to that ploughed by a pair. Neither was there a significant difference in yield for the two cultivation systems. [Table 8]

Discussion

The on-farm trial using oxen as singles has shown that the technology is feasible on a small amount of land. Only a few technical problems have arisen and the greatest constraint to an expanded use of single oxen is that farmers have to participate in communal activites two days a week. These activities consist of ploughing on cooperative land from the PA, or on land that belongs to the infirm or to members of the army.

Farmers are not allowed to use a single ox for communal activities as the Peasants' Association fears that they will not cover their assignments with only one ox. On-station research is therefore necessary to determine the maximum potential of a single ox on various soil types in the Debre Zeit area. Farmers also complained about the shortage of feed. The performance of oxen under nutritional stress is as yet poorly understood and these trials are too limited to provide the necessary technical information. On-station trials need to be done to determine work output of single oxen of local breeds under different levels of nutrition.

Cows for Draught

Because of the importance of oxen power in Ethiopia, a high fraction of the bovine biomass kept by smallholders is accounted for by oxen. Farmers attempt to produce their own replacements and to this end, they keep on four or five other cattle. If cows could be used for draught without a serious loss of performance, then the opportunity would exist for a substantial restructuring of holdings.

ILCA's research on the use of crossbred cows to improve smallholder dairy production, has led to increases in livestock holdings. Farmers were still keeping local cows in addition to the crossbreds for milk and for the provision of draught. If successful, this multipurpose use of cows would allow farmers to make more efficient use of feed and

to sell much of their unproductive stock.

During 1984, nine farmers used crossbreds for cultivation. These farmers were on average 40 years old and had an average family size of nine. The average size of their holding was 3.5 ha with a range of 1.9 to 5.3 ha (cv 28%). On average 82% of the land was sown to cerals (mainly teff), 12% to forages (oats and vetch), and 6% to pulses (horse beans, chick peas). Regionally, more than 30% of the cultiv land is sown with pulses. Cereals require around 60% more draugh power and labour inputs per hectare than do pulses. Using cows for traction greatly increases the availability of draught, hence the greater fraction of cereals.

The test farmers had relatively large livestock holdings. They owned between two and three crossbred cows and three crossbred young stock, two local cows, one or two local oxen, and four other local cattle of mixed ages, a few sheep or goats, two donkeys and four chickens.

These holdings are substantially higher than the regional average. On average the value of livestock holdings of test farmers was $ 2200 or more than three times that of a traditional holding.

Six of the farmers did almost all of their cultivation (more than 80% of the land) with the crossbred cows. The remaining three received their additional cows late in the season and as a result they used them to cultivate only 40 % of the total of the land. On average, around 450 animal-hours were necessary for land preparation and planting. Cows were worked four hours per day for the seedbed preparation, but six hours per day during the seeding period.

The crossbred cows were approximately 40% faster than the traditional cows in cultivating. Farmers achieved a greater ploughing depth (17 cm vs 15 cm) and did a larger number of cultivations than with the traditional method (five or six vs four). Teff yields of cow traction farmers averaged 1320 kg/ha, against 1000 kg/ha for other farmers in the area. This, however, is also attributable to their greater use of

chemical fertilizer. Farmers with crossbred cows have significantly higher cash incomes than traditional farmers and a substantial fraction of this income is used to purchase additional farm inputs such as fertilizers.

The cows needed some training before they could be used for draught. This took ten to 15 days. One method was to pair them with an ox. Another one was to have them tied and led by a second handler. One cow was too wild and could not be trained. The number of working days averaged 40 (ploughing only). Adjusted average milk yields of working cows over a 305 day period were 1230 kg (cv 32%). On working days the penalty on milk yield was around one liter of milk, or 15-20% of daily production. In the cultivation season of 1984, farmers stopped working their cows only a few days before calving, and worked them again in some cases the day after. They liked the idea of one animal providing simultaneously milk, meat, manure, and draught power.

Discussion

The on-farm trial has shown that the use of crossbred cows for traction and milk is feasible, and that it has minimal effects on milk production. Farm income can increase dramatically through an increase in area cultivated, a higher fraction of land sown to cereals and the opportunity of greater livestock sales. Farmers could also finish their cultivation earlier, and use the saved time for other enterprises. The sample size of the on-farm trials was, however, too limited to capture the effects on cow fertility. Also, the draught cows had much lower milk yields than the dairy test farmers and EPID farmers reported in the first section of this paper. This was because they were not good cows to begin with, and not due to their draught work.

On-farm trials gave the researcher clear indications on how farmers relax certain conditions considered by researchers to be ideal. Researchers assumed the farmer would stop working the cows 30 days before calving and for 40 days after calving. In reality, farmers

accepted much smaller time periods. It is also not yet known what the performance of such cows is under greater nutritional stress.

The practical problems reported by farmers arising with the use of crossbred cows for draught are mainly related to training the animals. Although in most cases it took only ten to 15 days, two farmers complained that it had taken them two to three months before the cow was fully adjusted to work. Farmers were also looking for practical ways to plan seasonal breeding to avoid calving during the cultivation season.

Other problems were not related to using cows for draught but to the management of crossbred cows in general. These include issues related to breeding, marketing, fodder production, calf rearing, and animal health.

Differences in management between individual farmers complicated the evaluation of using cows for draught. It also seems particularly difficult to find ways for smallholders to synchronize calving with period of low work demand. Most importantly, given the small sample size it is impossible to investigate and appraise the technical tradeoffs between work output, milk production, and fertility. This important gap in knowledge will have to be addressed in a formal on-station experiment.

OUTLOOK

On-farm trials with livestock are most useful to assess adoption rates of new technology, to appraise farmer adoption problems, to evaluate the impact on productivity and income, and to identify areas for further station research. On-farm trials are not suitable to establish technical relations and technical trade-offs between various variables and treatments. Most sample sizes do not allow for an evaluation of the impact of certain treatments on long-term productivity.

On-farm livestock researchers face a continuous struggle with what is theoretically desirable, and what is practically possible for these aspects of sample size. The only practical way out of this difficulty is for the researchers to lower objectives so that the information obtained is still useful.

The experience of ILCA's Highland's Programme at Debre Zeit indicates that the most relevant criterion for success of on-farm trials is whether the farmer uses the technology and how he modifies it to suit his multiple objectives. The limited period during which ILCA's trials have been conducted does not yet allow for an ex-ante assessment of the impact of these technologies in a larger development setting without ILCA's direct involvement. Additional experience, is being gained through a development project jointly set up by ILCA's Famine Relief Committee and the Ethiopian Ministry of Agriculture. The project involves 650 farmers who have been supplied with 1 ox, seeds, and single ox ploughing equipment. Results of this experience will be of crucial importance for a further in-depth evaluation of the single ox technology.

FOOTNOTES

1. Within each Ethiopian province the administrative subdivisions are Awradjas and Weredas. Several Weredas comprise each Awradja.

2. The author is grateful to Tesfaye G. Hanna and Aklilu Assefa for data collection and to Wagnew Ayelneh and Kristien de Boodt for computation assistance.

3. Average adjusted annual milk yield (AAMY) = (total lactation yield/calving interval) * 365.

4. $MW = LW^{0.75}$

   whereby MW = metabolic weight and LW = liveweight. MW is a unit which on a comparative basis better reflects the use of energy for maintenance by an animal.

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Table 1. Comparison of characteristics of crops and livestock and implications for on-farm testing

Factor	Situation with respect to Crops	Livestock	Implications for Livestock OFE
Mobility	Stationary	Mobile	Difficult to measure and control non-experimental factors
Life cycle duration	Generally < 4 months	Generally > 1 year	Increases costs, and likelihood of losing experimental unit
Life cycle synchronization	All units synchronized	Units seldom synchronized	Difficult to find comparable units
Multiple outputs	Only grain/tuber and residue	Meat, hides, milk, manure, power	Difficult to measure/ value treatment effect
Nonmarket inputs outputs	Few	Many	Difficult to value
Experimental unit size	Small, divisible	Large, indivisible	Increases cost, risk to cooperator
Producer attitudes	Impersonal	Personal taboos	Difficult to cull, castrate, earmark
Management variability	Low	High	Difficult to isolate treatment effect
Observation units	Many	Few	Large statistical variability
Ownership	Individual	Often shared or inherited	Joint management
Resource attribute	Land tenure individual	Often communal land	Reduces motivation
Target audience	Individual farmer	Farm family	Increases management variability

Source: Adapted from Bernsten et al (1983)

Table 2: ANOVA of Average lactation yield (A), 305 day yield (B), AAMY (C), milk production per day (D), lactation length (E), and milk production per metabolic unit (F)

		A	B	C	D	E	F
	d.f.	pr>f	pr>f	pr>f	pr>f	pr>f	pr>f
Between EPID and test farms	1	0.0001	0.0001	0.0027	-	0.056	-
Between individual farms	27	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001
Number of calving	6	0.0067	0.0031	0.02	0.021	-	0.018
Year of calving	1	0.0001	0.0001	0.0005	0.0001	-	0.0001
		R^2=0.83	R^2=0.84	R^2=0.8	R^2=0.83		R^2=0.84

Table 3: Monthly milk production, conception, calving and calf mortality on test farms, and monthly rainfall (Average 1978 - 1984)

Month	Rainfall (mm)	Milk production (cow)	No. conceptions	No. calvings	Calf mortality
January	13	183	5	11	1
February	11	158	9	16	4
March	72	187	16	10	2
April	42	187	11	17	4
May	69	197	16	9	2
June	105	220	10	5	3
July	217	209	17	1	3
August	194	176	9	4	6
September	91	156	5	4	7
October	24	155	1	5	1
November	-	149	4	9	1
December	-	169	4	16	4

Table 4. Average lactation yields and lengths of 50% and 75% crossbred cows of 'test' farms and 'EPID' farms

Parameter	Test farms		EPID farms	
	50%	75%	50%	75%
average yield, kg	2219	1552	1741	1576
305 day yield, kg	1990	1397	1603	1450
average adjusted annual yield, kg	1858	1212	1538	1174
yield/day, kg	6.5	4.5	5.5	5.1
lactation length, days	347	340	320	310
dry period, days	102	98	95	188

Table 5. Average lactation yields and lengths before 1981 on 'test' farms

Parameter	Period before 1981	Period after 1981
average yield, kg	2433 1536	
305 day yield, kg	2175	1389
average adjusted annual yield, kg	1987	1284
yield/day, kg	7.0	4.6
lactation length, days	355	332
dry period, days	101	157
Concentrate use, kg/year	1086	339

Table 6. Productivity of crossbred cows under cooperative management

Parameter	Mean value
yield/lactation, kg	785
305 day yield. kg	781
average adjusted annual yield, kg	776
calving interval, days	419
lactation length, days	221
dry period, days	198
yield/day, kg	3.5
mortality of 75 % calves to 1 year	60

Table 7. Area cultivated and time need for ploughing by single and paired oxen at Debre Zeit, 1984

Number of oxen measured for work	soil type	area cultivated (m2)	no of passes	time needed (hours)	cultivation time (hours/hectare)
one	black	38374	5	543	142
	light	72671	7	1305	180
	Total	111045	-	1848	166
two	black	483179	8	6456	134
	light	113258	8	1815	160
	Total	596437	-	8271	139

Table 8. Cropping pattern and gross crop yields of single ox farmers at Debre Zeit, 1984

Crop	ultivated area (% of total)	Yield grain (kg/ha)	Yield straw (kg/ha)
teff	59	984	1646
wheat	14	1083	1701
sorghum	3	405	362
barley	2	1435	2292
rough peas	4	475	496
chick peas	11	609	619
horse beans	3	597	1073
vegetables	3	na	na
fallow	1	na	na

DISCUSSION

Q. Can you elaborate on the use of cows for traction and the effects on milk production?

A. Nine crossbred cows were used for traction--six were used to plow all the farmers' land, three came late and only plowed 40% of the land. The animals worked four hours per day on seedbed preparation and six hours per day during planting. The crossbred animals plowed deeper and carried out more passes over the land than local oxen. Milk production was 1230 kilograms over 305 days compared to 1990 kilograms per non-working crossbred cows. Local cows produced 400 kilos. Animals were worked up to calving and returned to work only one to two days after calving.

Q. Please explain the reasons for the high rate of calf mortality (42%) for up to two years of age? When did the majority of deaths occur?

A. Most deaths occurred before one year.

Q. In Asia and parts of Africa, oxen having gone through the dry season are too weak to plow the land and thus planting is delayed as much as one month. How important is this problem in most African situations?

A. Very important, but less so in Ethiopia because the dry season is cooler.

Q. Due to small size of sample, rigorous statistical analysis was not possible. Were accounting techniques which do not require statistical rigor used for some quantitative analyses?

A. Yes, partial budgeting and programming techniques have been used in analysis of data.

Q. Do you have any empirical data on adoption rate of the crossbred cows around the Debra Zeit site? The test has been going on since 1978, and given the high milk production of the crossbred cows, the farmers should adopt if they have found it acceptable.

A. No adoption survey has been conducted. Although farmers are interested in buying crossbred cows, the supply has been the limiting factor.

Q. I am puzzled by the statement that farmers' selection of shallow soils for use of single ox plows is a result of uncertainty over their capabilities. Do they make their decision based on short-term observations, or do they want to see long-term effects on the animals? If the former, why are they still uncertain?

A. Farmers are mostly concerned with short-term capabilities of the technology. However, in any introduction of a technology, it takes some time for farmers to satisfy themselves as to how it should be used.

Q. Is it appropriate to include 21% aborted calves in calf mortality figures? Calf mortality should be based on live births.

A. It is generally agreed that the abortion figure should not be included in calf mortality.

Comments:

We need to be careful in using crossbreeds of stock for on-farm trials. Such cross breeds may still need a higher level of managerial input beyond the target farmers as symptomized by high mortality rates. There may be need to further cross the stock to get a breed that is more environmentally adaptable. It's still more productive than the local stock, that requires a lower level of management than the first crossbreeds or it might be better to simply select from local breeds to

improve production.

The chairman asked me to comment on the issue of "where research ends and extension begins." It is my feeling that researchers usually end their research too early. It should be the responsibility of the researcher to carry the research up to the point where it is clearly shown that a so called "improved intervention" is workable and practicable for the farmer who is supposed to use that intervention. This phase should be carried out on farms with close collaboration of the farmer and the extension agency. It is only after that phase is successfully completed that the job of research is successfully completed.

Pastoralists in Nigeria (sub-humid zone) do not keep animals for plowing. The castrates are sold to farmers since the pastoralists see no purpose in fattening animals for plowing. The farmers keep one to three castrates, having sufficient resources to feed them. Because the castrates are well fed, pastoralists in turn hire the oxen from the farmers for their own farming. Farmers prefer the local breeds to crosses for management ease.

Experiments conducted in Niger show that one can know, with sufficient precision, the quantities of feed that are fed. But the animals also ingest feed coming from the household as well as from pastures. In such cases, the nutrients are hard to quantify. All this makes for an appreciation of the impact of feed supplementation of on-farm animals, and some of the difficulties involved.

ON THE ALLEGED DIFFICULTIES OF ON-FARM RESEARCH WITH LIVESTOCK

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INTRODUCTION

Several papers (Bernsten, 1982; Gryseels, 1985) argue that livestock on-farm trials (LOFT) are inherently more difficult than crops on farm trials (COFT). They adduce various reasons for this, such as the costs of monitoring a continuous production process and the extended period over which animal production occurs. The increased costs are said to result in lower levels of statistical confidence about the inferences made from the research, because of the smaller samples which can be measured at a given cost.

This argument confounds two issues. The first issue is the comparison of a crops research program to a livestock research program. The second is the comparison of experimental treatments in a livestock trial. The first issue is of choices in a research portfolio, once the decision to undertake on-farm research (OFR) has been made. It is improbable that a system would ever be faced with a strict choice since the sequences of events leading to OFR in crops or livestock would not often coincide. The second is relevant only when the decision to undertake LOFT has been made. Then there are genuine problems in deciding which methods to use and in executing the field work and the analysis. But these problems are different from those in choosing between COFT and LOFT. The distinction between the two issues is necessary for appreciating the real magnitudes of the difficulties in this kind of research.

The argument also ignores an important characteristic of research costs-- the marginal costs of adding sample units to a survey or to a trial are low. I have shown previously (McIntire 1984) that the share of internationally recruited professionals and of capital (e.g., vehicles and computers) in research costs per sample unit in farm management studies in West Africa is almost two-thirds of the total.

Since such costs would not increase with reasonable changes in sample size, only one-third of the total would be affected by changes in sample sizes needed to accomodate livestock trials. Costs affected by increasing sample sizes are those of low-paid enumerators and inexpensive materials, such as seeds, fertilizers, and bags.

The argument has two other shortcomings. It misses the point that much of what is relevant to improved animal production is crops research. For example, some of the papers presented in the recent ICARDA/IDRC workshop on this topic were reports of forage trials in which animals were not involved or in which they were not the only component. Second, it is also true that emphasis on the costs of non-treatment error ignores the possibility of different benefits from COFT and from LOFT. Relative benefits are a different issue, but they do need to be considered.

PROBLEMS IN LOFT

The following is a brief analysis of difficulties noted in the literature, in particular of 11 problems cited by Bernsten and by Gryseels. It refers to examples of the problems, to actual solutions from the literature, and to logical solutions.

Animal Mobility

Gryseels argues that this "makes it difficult to describe environment-livestock interactions, [and] to measure and control factors not included as treatments." Animal mobility is a source of non-treatment error. Such error is not unique in livestock research, because crops research has similar sources of non-treatment error. It is only if such error is greater in LOFT than in COFT that its costs would affect the choice of research program (the first issue). Relevant to the second issue--of the analysis of LOFT treatments--animal mobility introduces random error into the dependent variable, and it increases the costs of monitoring animal behavior. The principal factor related to mobility is pasture quality. This is

an issue of pastoral systems in which animals travel long distances over pastures of different quality. In high population density areas animals are less mobile; therefore, the costs of monitoring them are lower and potential variation is reduced. This error is a source of inefficiency in the estimate, but it is not a source of bias unless the error caused by mobility is correlated with one of the treatments.

Life Cycle Duration

This is the problem of the duration of animal production, and of the temporal pattern of reproduction. In choosing between COFT and LOFT, it is important because the costs of monitoring herds or individual producers for many years are high. The place to resolve this problem is not on farms, but on research stations where the long-term costs can be reduced. If the research problem is to estimate the reproductivity effects of a treatment, then this can be done with experimental herds more accurately than with producer herds. If there are sources of farm variation which are hypothesized to affect reproductivity, then these can be analyzed with simulation models (von Kaufmann, 1984) showing the potential effects of treatments and guiding the decision maker about the potential value of LOFT and the research methods necessary to realise it.

Specific sources of life cycle error in LOFT cited by Gryseels are the "risk that animals may die or be sold before the trial is completed". There are two kinds of risks: covariant and specific. Covariant risks affect the whole sample: for example, an epizootic. Specific risks affect sample units: for example, an accident to an animal. These risks are greater than with station research involving animals, but one should not exaggerate their importance. Mortality can be estimated by surveys before LOFT are done, so that the sample size can be adjusted accordingly. Adult mortality in African cattle tends to be under ten percent per year. A covariant risk in LOFT, such as a disease outbreak, has analogies in COFT, such as a drought. Second, covariant risks are not

correlated with the treatments, so that they do not introduce bias into inferences made from the results (the second issue). They may destroy the experiment, but the risk of this is not necessarily higher than in crops (the first issue). It is only if there is some specific risk related to the sample unit or to the treatment that bias is introduced and this can be discovered by the scientist. If it is a specific risk (e.g., a farmer sells an experimental animal), then it is probably unrelated to the treatment and simply results in the loss of an observation.

Life Cycle Synchronization

Gryseels argues that "crops of similar varieties are planted and harvested more or less at the same time [but] animal production is not synchronized..." The result is that it is "difficult to find comparable units." On the first issue, crop synchronicity is not necessarily a cost advantage. The asynchronicity of animal production spreads out the work load--there is not the peak involved in setting out yield plots and harvesting them as there is with crops work. There are also pronounced planting date effects in crops which are less reversible than in animals. If a crop is planted late then it cannot catch up; whereas if an animal loses condition in the dry season, then it can regain it in the wet season.

On the second issue, asynchronicity is mainly a problem with cattle, since the reproductive cycles of small ruminants are short. (For example, one productivity index for ILCA goat data is based on kid's weight at 150 days). Even for cattle, this difficulty is somewhat exaggerated. There are many studies of cattle reproduction in Africa (see Otchere, 1984) with large sample sizes across many cohorts and birth seasons. For example, if milk production is the dependent variable, then the sample size in one year is limited by the calving rate. Even in pastoral conditions, this is close to 50 %, so that there would be sufficient pregnant females to measure treatment effects within comparable groups. One study in India used 27 calves and achieved statistically significant results

by "blocking" supplemented animals by age and by weight (Agarwal and Verma, 1982). It is also true that many interventions are designed to alleviate peak production constraints, such as dry or plowing season feed shortages. Since such constraints are binding in briefer periods, then the asynchronicity problem is less important.

Multiple Outputs

It is argued that multiple outputs make economic evaluation of animal research more difficult. Such outputs include milk, meat, manure, draft power, and hides. This problem is a real one, but it is not like the others, since it is not a problem of detecting treatment effects but one of assigning values to the treatment coefficients. It is hard to imagine that this difficulty would induce a research manager to choose a crops research program over a livestock program and it is therefore largely relevant to the second issue.

It is also a problem whose impact on the second issue is somewhat exaggerated. Meat and hides are available only once per animal in well known markets, so there is no problem in measuring their values or in monitoring their changes over a long period. Milk and manure are available continuously and manure is not generally traded, so that there are monitoring and valuation problems. However, since the principal goal in LOFT is to test the marginal effects of improved technologies, the main dependent variable with some measurement difficulty is milk, since measuring marginal changes in manure output due to some treatment would not be a major research goal. (This is not to say that manure is not an important output—it is to say that its value is low compared to that of milk or meat, and that its value is probably not differentially affected by an experiment.) The valuation problem would not apply to milk since it is a traded good; admittedly some milk is consumed at home, and does pose a valuation problem, but the marginal quantity produced is probably going to be sold. The effect of draft power is not impossible to measure and to value, but some of the technical

difficulties in doing so (e.g., cultivation depth) are such that station research is probably required.

Non-Market Inputs

Gryseels argues that "smallholder livestock production systems depend on inputs such as child labor, [and] crop residues [...] which are difficult to value". Many of these inputs, especially child labor, are also used in crop production, so that the first issue would not always be raised by the valuation problem for non-market inputs. It is again hard to believe that difficulties in evaluating such inputs would make a research manager reject a LOFT program.

Under the second issue, since the problem is evaluating different livestock production technologies, we are still mainly concerned with marginal effects. Unless use of crop residues or of child labor is significantly affected by different treatments, it can be taken as a constant. If one evaluates feeding crop residues against mulching, then there is a valuation problem. However, because feeding residues, as opposed to grazing them, is more appropriate to high population density areas, then fodder markets can develop. (This was found in ICRISAT's sorghum work in India). Where such markets have not developed, then it is possible to survey current uses and to decide how to value them. Where residues are left in the field, then it is legitimate to assume that they have no alternative value.

Size of Experimental Unit

Gryseels argues that "Smallholder farmers have only a few large ruminants, and exposing these to trials and treatments exposes the producer to substantial risks in participating in the research." This is the problem with block (e.g., farmer) effects. Similar block effects in crops work—e.g., a disease affects one farmer's plots, and not another's—are estimated by replicates within a block. Such replication is said to be more difficult in animal work. There are two problems here. One is the causes of block effects, and these can

be estimated by measuring management variables, if the block effect is not purely random. If one has some real measure of the block (eg, watering frequency) then it is not necessary to have within-block replicates if the real cause is measured across farms. If one has only a qualitative measure of the block --such as a dummy variable for farmer--then within-block replicates are necessary. The choice between the real measure and the dummy variable approach is one of choosing between an approach which requires measuring more variables for a given sample size and one which requires more replicates of a given set of variables. These are very different approaches, and the former does not necessarily involve increasing sample size. The second problem is the risk of confounding treatment with block effects, leading to inefficient estimators of treatment effects. This again reduces the confidence of inferences made. While this is a genuine problem, it can be alleviated by replication and by stratification (as done by Agarwal and Verma), and it is mainly a problem of cattle. As noted above in the discussion of life cycle synchronization, the cycle of small ruminants is short and farmers might have sufficient animals to enable within-block replication (Tully et al., 1985). This is less likely to be true for cattle. However, one study in Lesotho used within-farm replicates in a study of a winter lick for oxen (Molapo, et al., 1982).

Different farmers have different resources, some of which (e.g., water, crop residues, small children, or cash) allow better nutrition or management. This fact creates two problems. One is sample heterogeneity, and the other is sample size. In a random sample, heterogeneity might be troubling, since the sample may include units drawn from more than one population, and increasing size might do more harm than good. In a volunteer sample, it is probably less important (and this hypothesis is supported by the nine cow traction farmers discussed in Gryseels 1985) because of selectivity bias in getting farmers with similar resources. In this case, there will be no treatment effect because of lack of variation in the treatment, not because of too much variation in the dependent variable.

Producer Attitudes

It is argued that livestock producers have attitudes toward their animals which differ from the attitudes of crop producers toward their crops and that these attitudes make some treatments difficult or impossible in LOFT. The examples cited by Bernsten are of eartagging, culling, and castrating experimental animals. Although I have only done a superficial review of the literature, I have found no examples of the latter two being proposed as treatments in smallholder LOFT in developing countries. Eartagging has posed practical difficulties, but my experience in Niger showed no farmer resistance in principle if the technique was explained clearly. This does not mean that mistakes in animal identification do not occur, but that it is possible to reduce them. These attitudes are genuine difficulties, but one should not exaggerate their importance.

Management Variability

It is argued that there is significant management variability in animal work; the tacit argument is made that this variability is greater in livestock research than in crops research. This argument has been discussed above in the sections about mobility, life cycle synchronization, and size of experimental unit. It is agreed that daily care must be monitored. However, since the two principal treatments in LOFT are health and nutrition, it is difficult to believe that there would be such negligence in the application of one, that the effect of the latter would be masked. If, for example, concentrate feeds are being tried then presumably farmers know that water is essential. If some health intervention is tried, then farmers know that nutrition is important. This knowledge would not eliminate all variation in the other variable, but it should eliminate extreme variation, or variation due to farmers' execution errors in the application of treatments. This does not eliminate the problem of different resource bases, leading to different management practices. That problem is not specific to LOFT, and it can be resolved by choosing homogeneous strata in the sample

so as to have sufficient numbers of observations in each stratum.

Ownership of Animals

It is argued that joint ownership and therefore joint management of animals constitute a difficulty. This is mainly relevant to the first issue, because owner consent is a condition for participation in LOFT. Once consent is gained then ownership problems should not affect incentives to apply treatments correctly. Consent presumably depends on prior resolution of the ownership problem within the management unit. The example cited by Gryseels of joint ownership is essentially that of animal entrustment, which is more common in pastoral areas than in smallholder systems. There are incentive problems in technology adoption by managers who are not owners, but they are not problems in estimating the returns to technology, only in analysing the distribution of those returns. On the second issue, if it were hypothesized that ownership characteristics, such as animal tenure, affected the outcome of the trial, then it is possible to test that hypothesis explicitly by including different tenure classes among the participants.

Resource Attributes

Gryseels argues that joint ownership of resources, such as pastures, "reduces motivation." It is unclear if it is meant that the resource attribute problem complicates the interpretation of the results because of poorly applied treatments, or whether it affects the motivation for farmers to participate in the first place. If the latter is meant, then this is again an incentive problem, which is relevant to the first issue. If there are common property questions, such as communally held pastures, then one would have to question the wisdom of doing LOFT on such properties. This is a well-recognized fact in the economic literature, and it only means that on-farm pasture experiments must be just that--carried out on farms which are privately held. If, for example, pastures are communal, then farmers or herders would be unable to set aside

individual plots for pasture improvement trials or they might deliberately select the worst areas, figuring that such areas are useless anyway.

Target Population

This is a particular version of the animal ownership problem. The difficulty is that target populations in a trial are hard to identify because of joint ownership of animals. It is partly a research resource allocation problem, and partly an incentive problem. Presumably the issue of the target population is determined by the needs and priorities of the research institute. While it is true that "livestock are managed by more than one person" (Gryseels, 1985), individual animals are usually owned by one person alone, which makes identification of the target population less complicated.

CONCLUSIONS

Bernsten's original list of the difficulties in LOFT was adduced as a set of reasons why research programs have been unwilling to use a valuable technique. Though I do not find those reasons convincing, they still stand as reasons why more of this kind of work has not been done. That is to say, research managers believed in them misguidedly. What can be done about this ? First, there should be a review of loft in smallholder conditions. I have only made brief reference to such work and someone who knows the literature could do better. Second, explicit cost functions for research need to be specified. Just as I previously argued that the cost advantage of rapid appraisal methods of rural economics research was exaggerated, I think that the cost disadvantage of LOFT vis-a-vis COFT is also exaggerated. (This is only a hypothesis--I have not proved this.) Third, the justification for LOFT, as opposed to livestock research on station always needs to be made very clearly. In the stampede to do on-farm work, it is possible that higher quality work, better done on stations, will be trampled.

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DISCUSSION

Comment:

Crop on-farm trials (COFT) can be done without much attention to livestock on-farm trials (LOFT) but not the other way around, which makes LOFT necessarily complex.

We need to understand the complementarity that may exist between crops and livestock before LOFT is undertaken.

Concerning the need to have substantial amounts of capital tied up in LOFT, I would argue that a case properly made in the overall research process, most researchers concerned with LOFT should be able to secure animals from national stations. Most, if not all, African states have large numbers of animals which could be used for LOFT.

Q. On designing on-farm trials, do we need to think as farmers or researchers? And do we look for convincing results or statistically significant results? This is a question of conceptual approach to on-farm trials?

A. There are biases in subjective measurements. When one goes for "convincing results" one seldom can go for objective measurement. In this case the design of on-farm trials should be done in such a way that statistical results are obtained.

Comment:

I would agree that the difficulties with LOFT are sometimes exaggerated. The problem cited can be solved, and has been solved, by some practitioners already. However, I do not think sample size should be increased without increasing the scientist's time commitment. If the additional farmers are only contacted by enumerators, a major

benefit of all on-farm trials, that is scientist-farmer contact for increased understanding, is not increased.

I believe it would be more profitable to discuss the differences rather than trying to claim LOFT is more difficult than COFT or vice versa. Milk is different from sorghum—it can be fed to calves or humans. Its value rises according to family:herd size ratio. A big herd vs. a small family means that more milk is left for calves or is sold as butter. Milk is sold in combination with grain. The price varies seasonally. This is compounded by dilution variations. Also milk is perishable.

Sorghum also has such complications as to labor arrangement. Payment in kind is common for sorghum. It can be used for consumption, for sale or for labor.

That is my point, they are very different, not necessarily more difficult.

To get livestock owners to cooperate in on-farm studies will depend on the type of study. At the descriptive stage, their cooperation is a function of their confidence in the researcher. But when the studies involve the application of methods which (according to the owners) might lead to damages to their animals, then their cooperation becomes more difficult. For instance, we have had no problem in Niger because we are at the descriptive state. However, in Mali, in order to use the fecal collection bags, we had to buy the animals from the owners with whom we had good relations.

SOCIOECONOMIC METHODOLOGIES IN THE DUAL-PURPOSE GOAT FARMING SYSTEMS RESEARCH IN WESTERN KENYA

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INTRODUCTION

This paper discusses socioeconomic methodologies applied in the farming systems research of the Small Ruminant Collaborative Research Support Program (SR-CRSP) in western Kenya. The SR-CRSP is concerned with research on types of goats with good milk- and meat-yielding characteristics suitable for small-scale farmers and their households. Such "dual-purpose goats" (DPGs) would provide extra milk and meat to enhance family diets and provide cash income in the form of off-farm product sales.

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A farming systems research (FSR) approach is applied by a multidisciplinary team of scientists in pursuit of program objectives. Team members collaborate with one another through the particular projects they represent. These projects include: Nutrition and Management, Feed Resources, Animal Health, Animal Breeding, Systems Analysis, Agricultural Economics, and Rural Sociology. Each project is headed by a resident scientist and staffed with counterpart scientists from MALD who acquire practical laboratory and field training as a prelude to further local and overseas training for advanced degrees in their areas of specialization. The emphasis on training serves another important objective for the SR-CRSP, which is to develop the institutional capability of the MALD for FSR.

For logistical reasons most of the Breeding Project work is conducted

at Ol Mogogo, a MALD station close to Naivasha (northwest of Nairobi in central Kenya). Similarly, research in the areas of systems analysis and animal health is based in Kabete, at the facilities of the National Veterinary Laboratories just outside of Nairobi. Otherwise, a substantial amount of the Program's activities are located in western Kenya, in that part of the Lake Victoria basin covering Kakamega District in Western Province, and Siaya and Kisumu Districts in Nyanza Province.

Those working in western Kenya include scientists representing the Nutrition and Management, Feed Resources, Economics, and Rural Sociology projects. Site work is also provided for under the Health Project (disease monitoring). Headquarters for the Program's western Kenya activities is the Maseno Veterinary Station, which lies a short distance northwest of Kisumu Town, on the Lake. Offices, a small laboratory, and stock barns are located at Maseno, as well as a flock of crossbred (Toggenburg X East African) DPGs kept for research and multipication purposes. The station is also the site of extensive forage experiment fields. On-farm work takes place in smallholder communities representing different physical and socioeconomic environments in the area surrounding Maseno.

The Economics and Sociology projects were built into the Kenya SR-CRSP from its beginning in 1978 and have operated continuously since then. Socioeconomic contributions to the overall research effort include: initial characterization of the western Kenya study area; identification of constraints to potential adoption by small-scale farmers; of a DPG enterprise collaborative work with biological scientists in the design and implementation of station and on-farm trials of DPG technologies; and regular evaluation of the latter.

In this paper, socioeconomic methodologies are discussed under three sub-headings, namely: small farm systems surveys, station and on-farm trials, and short term studies.

SMALL FARM SYSTEMS SURVEYS

Agricultural economists and socioligists were involved in small farm systems surveys of the target area during the period November 1980 to October 1981 in collaboration with agronomists, veterinarians, and animal scientists (Matthewman and DeBoer, 1982; Nolan, 1982). Overall objectives of the surveys were to characterize basic features of the target area and to identify principle constraints to DPG production on small-scale farm as a basis for designing and implementing relevant FSR directed at alleviating these constraints. The surveys were administered in two stages: baseline survey came first, followed by a long-term monitoring survey.

Farm Sample

The sample frame used for the small farm systems surveys (and which is still being used for SR-CRSP on-farm trails) is part of a nationwide stratified sample previously used by the Kenya Ministry of Finance and Planning in its first four Integrated Rural Surveys. This frame stratified the entire smallholder area of the country into various agroecological zones. Further stages of stratification led to the identification of "cluster" groups of approximately 200 households. Finally, twenty households were randomly selected to represent each cluster (Sands et al, 1982).

The SR-CRSP surveys made use of four clusters, containing 80 farm households. Two clusters are in the agriculturally high potential zone of Kakamega District; the second pair is situated in the medium potential zone of Siaya District. (SR-CRSP activities, however, were subsequently discontinued from one cluster in Siaya district due to a problematic enumerator who had damaged rapport with respondent farmers).

Enumerators

Arrangements were made with the Central Bureau of Statistics (Ministry of Finance and Planning) to provide enumerators to the Program and post them to each cluster. The enumerators were selected on the basis of their fluency in local languages and they took up residence within or close to their assigned clusters. Before assignment, they underwent a short training course at Maseno in order to become familiar with the survey objectives and methods. These same enumerators continue to serve the Program and have done so in subsequent surveys and other activities in the clusters.

Baseline Survey

The baseline survey was conducted using a single visit questionnaire composed of several modules. The household module provided information on household composition, land and capital resources, cropping patterns, and livestock types and numbers. The labour module yielded data on household labour supply and demand. The sociology module identified general outlook and attitudes of the people surveyed as well as local beliefs and practices relating to goat keeping and goat products. Finally, the animal management and health module provided data on existing livestock husbandry, health practices and problems.

Monitoring Survey

The monitoring survey was based upon information derived from the household baseline survey. It lasted a complete year divided into thirteen 28-day lunar cycles. According to Sands et al (1982), the lunar cycles have a number of advantages over the more traditional calendar months. First, all cycles start on the same day of the week and the time between individual farm visits is theoretically the exact same length. Second, biases resulting from always visiting the same household at the beginning or end of the month are eliminated. Third, it was possible to arrange a household visit schedule for each

enumerator that remained constant over the entire period of the survey. Thus, every enumerator knew which questionnaire module to administer to which household on any given day.

The monitoring survey recorded changes on each farm since the previous 28 days. Information recorded included: changes in household composition, land and capital resources, livestock inventory and disease incidence, status of field crops and individual animals, purchases of farm inputs, labour use in various farming activities, animal feeding and milk production, quality of livestock feeds, and prices at local livestock markets.

Principal Constraints to DPG Production

Data from the small farm systems surveys were analyzed by the SR-CRSP team of researchers including economists and sociologists. Socioeconomic constraints to the production of DPGs on smallholder farms in western Kenya were identified as follows: land, labour, and capital scarcities; inadequate livestock marketing infrastructure; and prejudices against goats and goat products. Biological constraints were cited as: lack of adequate quality feeds on a year-round basis; susceptibility of goats to diseases and parasites; and lack of a suitable goat genotype capable of producing surplus milk (beyond kid requirements) for human consumption.

Lessons from the Surveys

A number of lessons were noted from the small farm systems survey. First, it did not necessarily have to take a complete year to delineate principle constraints to DPG production by small scale farmers in western Kenya. A rapid appraisal approach might have achieved the same results in shorter time at lower cost. However, and second, the relatively long time taken for the initial survey provided ample time and opportunity for several scientists with different academic backgrounds to interact and appreciate each other's special contribution to the entire SR-CRSP program more fully. This may have

facilitated the subsequent design and implementation of station and on-farm trials in a more collaborative interdisciplinary manner which has been the hallmark of SR-CRSP activities to date. Third, the multidisciplinary approach led to a more complete identification of technical (biological) as well as socioeconomic constraints and more thorough characterization of existing farming systems in study areas than it would have been possible with a mono-disciplinary approach.

STATION AND ON-FARM TRIALS

Component (disciplinary) research designed to resolve the identified constraints to DPG production has been conducted both on-station at Maseno and on-farm in clusters since 1982 following the small farm systems surveys. The socioeconomic input has consisted of development of analytical models for economic analysis of technical biological data from component trials of prototype DPG technologies, economic analysis of the data, and sociological assessment of farmers' reactions and views to the trial DPG technologies which include DPGs, new feeds, and management and health practices.

Participation in Biological Experiment Design and Data Analysis

Economists collaborate with biological scientists in preparing research protocols for biological station and on-farm trials. Participation by economists ensures that relevant variables are included in the design of biological trials to facilitate subsequent economic analysis of the technical data that they generate. When the trials are completed, the Economics Project extracts the required data for economic analysis. The Economics Project has developed and is developing quantitative models for economic analyses of whole-farm systems in cluster ares as well as individual component research trials.

Linear Programming Model

A whole-farm linear programming (LP) model was developed from the small farm systems survey data and updated with data generated from station

and on-farm trials (DeBoer et al, 1982; 1983). The LP model was constructed for various farm-size labour categories. As is typical of most LP models, the model maximizes gross margin from specified farm enterprise activities subject to various constraints. It attempts to capture the more important elements of the farm's decision environment.

The basic structure of the LP model includes farm enterprise activities, constraints, and input-output coefficients. Several crops and livestock production, consumption purchasing and selling activities are specified. The constraints include monthly labour supplies, land, livestock feed supplies, human nutritional requirements, goat nutritional requirements, and cash availability. Input coefficients reflecting output productivity, or input requirement levels for each activity in the model, are also specified.

The important feature of the LP model is the embodied concept that a study of all parts of a farm system is necessary for understanding the complete system, or solving problems that stand in the way of its improvements. The model recognizes that a change in one component of the farm system may cause or require a change in one or more of the other system components as they compete for limited farm resources at their disposal.

The LP model was used to assess and simulate optimal resource allocation under existing farming systems in cluster areas and under systems with DPG technology and government policy intervention. The impact of DPG technology on farm incomes and welfare was simulated by incorporating various DPG genotype-management practice combinations of activities in the model. Most promising enterprises were identified as basic activities in optimal LP model solutions.

Accounting Models

The Economics Project has formulated two accounting models for quantifying costs and benefits of various component DPG technologies and management practices, namely the gross margin model and the partial

budget model.

The gross margin (GM) model has been used to determine relative profitability of various farm enterprises. It involves quantifying products of each farm enterprise and their farm-gate prices, as well as variable inputs used by the enterprise and their farm-gate costs. Enterprise GM is then calculated as the difference between the value of enterprise products and cost of enterprise variable inputs. Enterprise GMs are computed per unit of land, labour and capital inputs as measures of short-run enterprise resource returns.

The GM model has been used by the Economics Project in developing input-output coefficients for the LP model, and for preliminary comparisons of the profitability of the DPG enterprise with other competing farm enterprises in clusters (Mukhebi, 1984).

The partial budget model has been used for economic analyses of selected component DPG technologies and management practices. It involves quantifying incremental costs and benefits of a test technology or practice over a conventional one, and determining the marginal net benefit or benefit-cost ratio (absolute marginal rate of return) of the test technology or practice. The benefit cost ratio or marginal rate of return is then used as a choice indicator for ranking and identifying economically most promising DPG technologies or management practices. Examples of partial budget analyses undertaken are summarized below.

a) Economics of Intercropping Forage Crops with Maize in Kaimosi Cluster (Mukhebi and Onim, 1985). This analysis quantifies economic costs and benefits of intercropping selected forage crops with maize assesses the impact of applying fertilizer to maize both in pure stand and intercropped with forage crops, and identifies economically most promising maize/forage intercrops for the target area.

b) Economics of Pre-weaning Kid Feeding Practices at Maseno

Research Station (Mukhebi and Sidahmed, 1985). This analaysis quantifies economic costs and benefits of various pre-weaning kid feeding practices, assesses the impact of supplementing milk with forage in such practices, and identifies economically most promising practices.

c) Economics of Internal Parasite Control Among Goats (Mukhebi et al, 1985). The analysis quantifies economic costs and benefits of controlling worm infestation among goats and assesses the economic performance of different breeds of goats under both infested and uninfested conditions.

d) Economics of Simulated Pre-weaning Kid Rearing Practices for the East African Goats in Hamisi, Western Kenya (Mukhebi et al, 1985). This analysis quantifies economic costs and benefits of various simulated kid rearing practices, assesses the impact of improved forage in such practices and identifies the economically most promising practices.

Lessons from Economic Modelling and Analysis of Biological Trials

Formulation of economic models and their subsequent applications to the analysis of results of biological trials has yielded several notable lessons. First, the input from other collaborating disciplines is indispensable in specifying input-output (technology) coefficient levels that reflect more accurately both the real world and simulated farming systems performance. However, and as a second point, other scientists appear to be somewhat apprehensive of economic evaluations of the results of their research trials. They seem to fear that economic analysis of their results will reveal them to be "uneconomical". As one researcher put it, "just analyse my data but for heaven's sake don't tell me my work is uneconomical". Nevertheless, when these scientists see results of economic analysis and their interpretation, they appreciate economic input more, and become more cooperative and less fearful of the "butcher", as one colleague characterized the economist. A third point bears on some

discontinuity in the Economics Project work due to staff turnover. The researcher who constructed the initial LP model simply went away with it when he ceased working with SR-CRSP. This meant that another LP model had to be formulated from scratch to continue with the whole-farm evaluations and simulations of the evolving DPG technologies and management practices. The lesson to be drawn here is that as staff turnover is a regular feature of FSR, careful documentation of all research activities is vital for program continuity. This would save time, effort and funds that would otherwise be wasted in repetition of lost work.

Sociological Participation in On-Farm Trials

The Rural Sociology Project seeks to contribute to the SR-CRSP on-farm work over the long-term by using both formal and informal observational techniques to monitor research activities in the clusters, including farmers attitudes and opinions towards DPG trials and associated work in feed development, management, and health practices.

Participant Observation by Field Enumerators

The Rural Sociology Project has been a component of the SR-CRSP in Kenya from the beginning, but there was no long-term resident scientist posted until late 1982. Since that time, the project has worked very closely with the Program's field enumerators.

In the process of living and working in their respective cluster areas, the enumerators have become known and accepted by the local residents. Regular, long-term interaction with these people has given enumerators an intimate view of community life. Communication is no problem since the enumerators are native speakers of the languages common to their areas. All of these attributes combine to make enumerators ideally suited for the role of "participant observers" in the various study sites.

"Participant observation" is an approach commonly employed by social

researchers, especially social anthropologists, when involved in long-term community studies. The technique is self-explanatory: the investigator serves at once as an "actor" and a "witness" of community life. A participant observer operates informally to gather "qualitative" (as opposed to more formal and "quantitative") information on various aspects of people's behaviour and beliefs. The approach is open-ended, and frankly impressionistic and opportunistic in nature: casual conversations, chance remarks, visits to respondents' homes and farms, encounters at market centres or neighbourhood meetings, etc., are all potential sources of interesting and revealing anecdotes about the way people live and think about themselves and their environments. Although it may sound very elementary and perhaps trivial (after all, people everywhere are in a sense "participant observers" of their social settings), participant observation as a research tool demands a fair measure of discipline: careful records of observations need to be made, and doubts and questions that arise need to be followed up. Moreover, one must develop a strong degree of sensitivity and attentiveness in order to pick up relevant "data". In time, even though participant observation is part and parcel of everyday life, it can also be refined as a conscious and deliberate component of fieldwork endeavours.

SR-CRSP field enumerators have been encouraged to develop their skills as participant observers by maintaining field journals for recording their experiences and impressions of, and thoughts and comments on people's behaviour and attitudes. Of particular concern have been such matters as gender roles and age gradations in the division of household and farm labour, livestock and crop management practices, land use, off-farm employment, and the stock and forage activities SR-CRSP researchers carry out in the study areas. By reviewing their notes with Sociology team members from time-to-time, and participating in evaluation and write-ups of observations collected, the enumerators have been able to enlarge the appreciation of local people's priorities, problems, and needs -- an appreciation vital to successful development of alternative smallholder production strategies.

Formal Interviews

Participant observation and regular journal recordings by the enumerators complement the periodic use of formal interviews with farmers in sociological investigations of ongoing work in the clusters. To cite one example, there is ongoing work being done in conjunction with the feed resources project in testing different forage producing alternatives in farmer's fields. Sociological input to the study is based on routine observations by the enumerators as well as results of formal questionnaires administered in the communities. In addition to monitoring in a more structured way farmers' reactions nd preferences vis-a-vis the Feed Resources trials and interventions, data are collected through the questionnaires on past and continuing methods of feed/forage production in the study communities, and reasons underlying changes in people's patterns and preferences are identified. By placing the Feed Resources trial alternatives in the context of established practices, the Sociology Project may be able to offer better informed commentary on the feasibility of these alternatives to the Feed Resources team.

Lessons from Sociology Participation in On-farm Trials

The involvement of sociologists in technical on-farm work in the clusters has been of mixed issue. Of special concern are the difficulties of effectively communicating to non-sociologist colleagues ideas and recommendations derived from observational work based on "soft" evidence derived from open-ended interviews or the recording of casual events, visual and mental impressions, etc. Partly this can be attributed to differing styles and modes of data collection which exist between the social and biological or technical sciences. Technical scientists are, by virtue of their training and research orientation, most comfortable with "hard" facts and figures derived from closely controlled experiments and statistical inference. Thus, experience in the Program has shown that when the presentation of sociological findings is couched in less discursive, more formal terms, where highly structured data collection techniques and numerical measures are

emphasized, the problem of communication and acceptance by technical colleagues is considerably eased.

But it seems that the problems of effective communication go deeper than this, judging by some of the reactions to sociological inquiry and commentary that have been forthcoming. There have been times when biological scientists have been positively irritated with sociologists, regarding the latters' work as meddlesome and a violation of professional "turf". Observations and suggestions which are intended to be helpful may be taken in just the opposite fashion, even when the attempt is made to present them tactfully. One may be met with extreme defensiveness, with the attitude of " what do you know about these things anyway?" The role of the sociologist therefore has not been a particularly easy one to fulfill, especially on those occasions when one bears tidings that technical scientists are not pleased to hear -- perhaps not even wanting to hear in the first place. In retrospect, it would have been wise to have spent more time with colleagues in the early stages of the Program in order to better acquaint them with the procedures and style of sociological work, and its attendant difficulties.

SHORT-TERM SOCIOECONOMIC STUDIES

The SR-CRSP Economics and Sociology Projects have conducted a number of studies in clusters and surrounding communities aimed at generating socioeconomic data to supplement data from station and on-farm biological trials. These studies provide a better base for assessing potential farmer adoption of DPGs.

Socioeconomic data are collected from primary and secondary sources. Primary sources include surveys and case studies of target farmers, local agricultural extension officers, local businesses and other relevant respondents such as community leaders. Secondary sources include farm records and public documents, especially from the Ministry of Agriculture and Livestock Development.

Prior to data collection, a research protocol for a new study is prepared in collaboration with the other scientists. The protocol includes the experiment number, title, place of study, names of principle and participating scientists and support staff (including an estimate of each individual's time input), the justification for the study, study objectives and hypotheses, procedures to be followed (including variables about which data are to be collected), an activity chart, and an itemized financial budget.

For each study, a questionnaire or an interview guideline is prepared for data collection. The questionnaire or interview guideline is designed in a way that enables all relevant data to be collected in as short a time as possible.

Trained enumerators are employed to assist with data collection. They are made to clearly understand the purpose of the study, what data are to be collected, the design of the questionnaire or interview guidelines, and how to ask or interpret the questions to respondents.

Before primary data sources are used, as much of the required data as possible is extracted from secondary sources using the questionnaire to save time and cost. The partly pre-filled questionnaires are then used by the scientists and enumerators to collect data from the respondents. For some studies, one day's visit to a respondent is adequate to collect data based upon the respondent's memory and available records. For other studies, enumerators may visit respondents two or three times weekly, for an extended period of several months or through a complete crop year, with less-frequent visits by principle scientists for supervisory purposes. Examples of socioeconomic studies undertaken are summarized below.

a) Some Relations Between Farm Characteristics and Herd/Flock Health Indicators on a Sample Farm in Western Kenya (DeBoer and Mortimer, 1983). A socioeconomic assessment was carried out on factors influencing current types and severity of animal health problems and measures, and animal management

and herd/flock health. The aim of this study was to assist in the planning of an effective animal health program for the SR-CRSP.

A farm survey was conducted in Kakamega and Siaya districts in mid-October 1980 and late January 1981. Three locations were randomly selected from each district; three sub-locations were randomly selected from each location. A list of farmers who owned goats was constructed for each sub-location with the assistance of local veterinary officers, animal health assistants and assistant chiefs. Farmers were then visited until the pre-selected sample size for each sub-location was filled. A socioeconomic questionnaire was administered in conjunction with regular sampling of animals carried out by the Animal Health Project.

b) Consumer Acceptability of Goat Milk Products in Western Kenya (Boor et al, 1983). The aim of this study was to determine whether consumer acceptability of goat milk products would be a constraint to the establishment of a DPG production system in western Kenya. Seventy secondary school students were requested to sample four fresh dairy products: goat milk, cow milk, goat cheese, and cow cheese. Following tasting, the students assigned each product a score between 1 and 5 (1 = excellent, 5 = distasteful). No significant difference was found between the scores for goat and cow dairy products.

c) Problems and Prospects for Small Scale Tick Control Method: Some Observations on the SR-CRSP Dipping Trials in Kakamega and Siaya Districts (Reynolds et al, 1983). Since March 1982, the SR-CRSP Nutrition and Management Project has been conducting field trials with regular dipping of sheep and goats as a low investment method of tick control in cluster areas. A number of crossbred DPGs had been introduced on a trial basis in the clusters and the exercise in tick control was partly to ensure that the DPGs were kept free of

tick-borne diseases. It was also designed to test the potential of dipping as a component of small ruminant husbandry practices. A sociologist, an economist and an animal scientist visited dipping sites in each cluster with the assistance of an enumerator. They collected relevant data through discussions with farmers participating in the dipping trials and by their own observations of the dipping exercise.

d) Analysis of Household Consumption in Western Kenya During the Short and Long Rains with a Comparison of On-farm Producing Food and Off-Farm Food Purchases (Nyaribo, 1983; Nyaribo et al, 1984). The objective of this study was to compare consumption of on-farm produced foods with off-farm purchased commodities, and assess the impact of season on the consumption pattern. A household consumption survey questionnaire was administered by enumerators to a random sample of 20 respondent households in each cluster.

Data were collected in April and June 1981, October 1982, and in April, June and October 1983. Each household was visited during one week in the relevant months. Respondents were asked to recall types and quantities of food consumed over the previous seven days. They were also asked the cost of purchased foods consumed, or if it was farm produced, to value it. A range of market prices was collected from selected markets in cluster areas for verifying farmer values of farm-produced products.

e) Implications of Family Labour Use for Adoption of the DPG Enterprise on Small Farms in W. Kenya (Nyaribo et al, 1984). The goal of this study was to quantify labour supply and demand on farms with DPGs in clusters and compare labour requirements between the DPG enterprise and other farm enterprises on these farms. Data were collected for six months, March to September 1983, through farmer interviews

using a questionnaire, and were verified by some field observations of farming activities.

f) A Socioeconomic Evaluation of the DPG Enterprise in Small Scale Farming Systems in Western Kenya (Mukhebi et al, 1984). This study provides a preliminary socioeconomic evaluation of the DPG enterprise in cluster areas. It assesses the economic benefits and costs accruing to farmers through gross marginal analysis, and farmers' attitudes and reactions in regard to the enterprise.

Input-output and attitudinal data were collected from 26 cluster farmers who had been given trial DPGs. Recall data were collected through single-visit farmer interviews and conversations with the farmers by economists, sociologists and enumerators. Gross margins were computed for major farm enterprises including the DPG enterprise and compared on a per unit input basis for land, labour and capital resources.

g) Seeking the "Udder" Truth about Goats in Western Kenya: Conversations with Community Elders (Reynolds, 1984). This study, as with b) above, assesses consumer acceptability of goat milk, this time from the point of view of community elders, who served as key informants. They were identified on the basis of their long association with the communities they lived in, the rich stock of personal experience and oral history they possessed, and their willingness to submit to interview. The SR-CRSP enumerators assisted the sociologists in identifying the elders. Fifteen men and women aged 65 to 80 years were interviewed. Formal questionnaires were not used for the interviews. Instead, a set of interview guidelines was used to structure conversations. Short notes were taken during the interviews and later transcribed into more complete form for review and discussion among the sociologists.

h) Extension Services and the Smallholder: A Report of Preliminary Findings (Reynolds, 1984). The aim of this study was to assess the structure and performance of existing livestock extension service and determine its potential capability for delivering DPG technologies to small-scale farmers in western Kenya. Using questionnaires designed with the collaboration of the Economics and Animal Health Projects, the Sociology Project interviewed all livestock extension and technical personnel in five admindistrative division where SR-CRSP had existing or planned study sites. The personnel interviewed included Veterinary Officers, Assistant Animal Production Officers, Dairy Development Officers, Animal Health Assistants, and Junior Animal Health Assistants. A total of 62 persons were interviewed through single day visits. Technical data related to disease incidence and livestock census were collected through questionnaires left with officers to be returned later. A second part of the study focussed on farmers' experiences with extension services. A sample of about 100 farmers was randomly selected from villages in the same five administrative divisions covered in the first part of the study. Each respondent farmer was visited at least once, and follow-up visits were made where necessary. Basic farm profiles were collected and respondents were asked to relate their views on the availability of extension services, and the positive and negative experiences they have encountered.

Lessons from Short-Run Socioeconomic Studies

The short-run socioeconomic studies discussed above have tended to cover a wider area than the biological trials which are confined to cluster areas. One result of this has been increased awareness of SR-CRSP activities amongst a larger audience of farmers, which in turn has led to increased requests for DPG trials to be conducted in other areas. While such a development can be read as a positive demonstration of general farmer interest in DPG production, it has also

created problems in that farmers develop expectations about participating in the trials which cannot be satisfied, due to lack of enough experimental animals for distribution, and lack of personnel to conduct more widespread monitoring.

With studies conducted in established cluster areas, it has become apparent that repeated interviewing of the same farmers over a long period of time has tended to wear down the patience and cooperation of some of the farmers. Cases of "respondent fatigue" are not widespread, but it does seem that certain farmers have begun to feel a bit "stuck" with the research program, particularly amongst those who have been involved from the early days.

Cases of "enumerator fatigue" also bear mention. The core of four enumerators occasionally expressed dissatisfation with their circumstances. The enumerators have worked for the program in western Kenya since its beginning without any opportunities offered to them for advancement of their careers. This has led to a feeling of "let down", as they have witnessed more technically qualified MALD staff come and go on advanced training, locally and overseas. It has also been noted that when left to themselves in the field, some enumerators arrogate to themselves more responsibilities in the name of the research program than their contracts stipulate. This has damaged rapport with some respondents and led to their non-cooperation with further research activities.

SUMMARY AND CONCLUSIONS

Economists and sociologists have applied a variety of methodologies that have yielded a number of instructive outcomes. Experience with the initial small farm systems surveys of the target area indicated that while similar data could probably have been assembled more efficiently (with less time at lower cost) using a rapid appraisal approach, there were nonetheless some advantages gained through the year-long exercise. The long-term interaction of scientists from different disciplines and backgrounds provided an oportunity for them

to better appreciate one another's contribution to the entire research program. Their combined efforts fostered more thorough constraint identification, and set the stage for collaborative and well-thought-out design and implementation of the subsequent station and on-farm trials.

Socioeconomic involvement in the design and implementation of biological trials ensured generation of more complete technical data ameneable to socioeconomic evaluation. Mathematical programming and accounting models, as well as informal and formal social impact assessment techniques, have been employed. These evaluations quantified benefits and costs, and assessed farmer acceptability of alternative DPG technologies and management practices. Short-term socioeconomic studies generated supplementary data to augment station and on-farm biological data and provided a better base for assessing potential farmer adoption of DPGs.

Various lessons are drawn from the experiences of economists and sociologists with station and on-farm trials and short-term studies. First, the input of biological scientists is indispensable in generating more realistic input-output physical data for socioeconomic evaluations. Second, as staff turnover is a regular feature of FSR, careful documentation of research activities is vital for program continuity in order to avoid repetition of work and save time, effort and funds. Third, generation of farmer awareness of on-farm trials beyond sample farmers creates a demand for the extension of such trials that might not be met with available resources. Fourth, prolonged use of the same respondent farmers and enumerators tends to wear out their patience and cooperation.

A fifth lesson is that socioeconomic involvement in the FSR has not always been gladly received by some of the other scientists. Reactions of apprehension and defensiveness have been noted, due in part to differences of style and procedure existing between social scientists and their biological or technical colleagues, and in part to the protective feelings that are aroused when professional "outsiders"

begin to offer judgements, sometimes not laudatory, about the worth of one's research efforts. However, over time, as colleagues have acquired greater familiarity with socioeconomic interpretations and their significance, collaboration has been facilitated. Still, looking back on the experiences, it seems that a more deliberate effort should have been made to allay any doubts and fears harboured by colleagues about the conduct and motives of their socioeconomic counterparts.

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DISCUSSION

Q. Have you brought along the Extension Service with small ruminant CRSP?

A. We are now, but maybe this was one of our weakest points in not getting Extension involved earlier in the CRSP. We recommend that Extension be involved much earlier in all FSR projects.

Q. Has Extension been involved in the Kaduna Project in Nigeria?

A. Yes, since the beginning we have involved Extension administration on advisory committees and now at the field level. We are using agents to serve as enumerators. This is an important point and should be addressed at the outset of a FSR project.

Comment:

The problem of lack of availability of Extension personnel could be an advantage if researchers assume a dual role of research and extension. This could enhance relevance of research to the farmers.

Q. Your project has raised some apprehension and defensiveness by some of the other scientists. If all the scientists were involved throughout the process of FSR, it might help to ease these problems and enhance and create an appreciation in a shorter period of time. If the results of FSR can have an immediate impact on ongoing research on future research programs, some of the problems mentioned will be avoided. Would you like to comment on these points?

A. We have been doing precisely what you have mentioned. Multi-disciplinary teams consisting of social and biological scientists have been involved in the project from the beginning. In spite of their involvement, the problem has been there.

Through time, the situation has changed and now there is better appreciation of the approach. The problem stems from our academic training which was not at all multi-disciplinary. We hope that as the FSR methodology develops it will find its way into college and university classroom situations.

Q. You mentioned the need for economic analysis in making selections between a given number of interventions prior to on-farm testing and research. In my opinion, this can be counterproductive, as benefits of interventions may not all be determined from an input/output type of analysis. There is, therefore, the problem of eliminating a potential system for the farmer through prior economic evaluation. Do you agree?

A. We do try as much as possible to consider not just the monetary issues but also the potential socio-cultural issues. We have a sociologist who works very closely with me on these issues.

Q. You indicated that four different breeds of dairy goats would be used in crossbreeding with local goats to give a dual purpose animal. What is the source of the parent stock for the initial stages of the program and for the future?

A. The animals are imported from Holland and bought from dairy goat farmers in Kenya. For the future, it is hoped that parent stock for production of sires for crossbreeding would be kept on government farms for purchase by farmers.

Q. How is the cost of thse animals computed in the economic analysis of the project?

A. At present, costs of animals are borne by the program and the animals are distributed free to the farmers. To put a price on these animals, some were sold in local markets along side local animals and it was observed that premium prices were paid for crossbred animals.

Q. The situation you described is primarily a cropping system. You implied that expansion of cropping reduced the livestock in the area. What have you done interms of crop improvement which is the primary interest of the farmer?

A. Yes, we are doing something in terms of dual purpose crops such as sweet potatoes and pigeon peas. We are also trying to identify forage species that would help cropping through improving soil fertility.

Q. From the presentation, it is evident that this is a worthwhile piece of research and very well done. However, at some time, won't it be necessary to justify the total investment in research on a rational cost/benefit basis?

A. The project conforms to government policy but the Minister of Agriculture is very concerned about the declining availability of livestock products. Farmers response is very good and all indications are positive. No social cost/benefit has been done on the investment in research.

Q. What advice do you give to farmers on how to feed goats during the planting season, since the goats are tethered?

A. The priority of feeding is up to the family. Farmers go early to the fields and on return bring browse/grass to the goats.

DAIRY PRODUCTION SYSTEMS IN SMALL HOLDINGS IN GEZIRA AREA OF SUDAN - A CASE REPORT OF THE GEZIRA DAIRY COOPERATIVE

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THE GEZIRA IRRIGATED SCHEME

The Gezira scheme that lies between the White and Blue Nile is the oldest and most important agricultural scheme in Sudan. It was established with the objective of increasing crop yields particularly with export crops such as cotton. It was also intended to increase the tenants' income and governmental revenue. The scheme has a total area of 2.3 million feddans (approximately 1 million ha: 1 feddan = .42 hectares) subdivided into 107 blocks, 54 of which are in the Gezira area and the rest are in Managil extension. The whole area of the scheme is irrigated, by gravity, from the Blue Nile. The only appreciable rainfall is during July and August, however crops are regularly watered and water is available throughout the year. Land is intensively cultivated according to a four-crop rotation in which the main crops are cotton, wheat, groundnuts and sorghum. One fourth of the land is left fallow, for a season before returning to cotton cultivation. The tenancy is forty feddans distributed equally between the crops and fallow: ten feddans each (except for sorghum and groundnuts which share ten feddans in the rotation). Vegetables and fodder are produced in small areas scattered in the scheme. The scheme comprises 12% of the total area cultivated in Sudan, and produces 80% of the country's cotton, 70% of the wheat, 30% of the groundnuts and 12% of the dura (sorghum grain).

Animal nutrition in the Gezira scheme

Livestock in the Gezira include cattle, sheep, goats, camel, and donkeys. The latter two are used for transportation while cattle, sheep and goats are used for milk and meat production. Livestock thrive mainly on agricultural crop residues and experience episodic shortages of feeds during the summer months (May-July). Animals are

generally in poor condition, of low productivity, with long calving intervals and reduced fertility—a reflection of inadequate feeding and poor management.

The agricultural calendar (Table 1) indicates that while crop residues are available for livestock during a good portion of the year, for some months animals have very little to eat. According to availability of crop residues at different times of the year, most farmers follow the feeding strategy given below.

December/ January	feeding of groundnut straw (some is sold to commercial beef producers)
January/ February	feeding sorghum straw (some is stored and fed later)
March/April	grazing cotton fields
May/July	a starvation period, animals thrive on dura and wheat straw which is fed at night, but the majority are turned out loose to scavenge on whatever they find from the remaining crop residues. Very little concentrated feeding is practiced. Animals generally lose condition and losses of livestock are often reported.
August/Nov	grazing on fallow and post-harvest areas because appreciable rains fall during July-August. In addition, animals graze the canal banks.

Establishment of the Gezira dairy cooperative

It has long been debated whether or not animals should be integrated into the Gezira Irrigated Scheme. Advocates of this integration argue that animals can contribute to farm revenue and provide meat and milk. Little has been done in this regard, on the contrary, some hardliners even go to the extent of considering animals as crop pests! Tenancies (40 feddans each) are leased to farmers on a production relation system, whereby farmers cultivate a mix of crops set by the Gezira board. Forages are not part of the rotation, and farmers are not free to cultivate whatever they want, even if their livestock need forages.

In July 1981, a new production relation system was formulated. It is

based on land and water rates for each crop, charged to tenants individually. The Board of the scheme provides services at cost (land preparation, watering, weed and pest control, etc.) and is responsible for the technical supervision and execution of the government's agricultural policies. The tenants (farmers) receive payment for their crops at the end of each season. A fixed percentage from the gross revenue is paid for social development.

In 1978, the Sudanese government negotiated a matching grant from the Irish government to establish a dairy processing plant for liquid milk in the central region of the Gezira. A formal survey was undertaken to estimate cattle numbers, milk production potential and the possibilities of marketing pasteurized milk. The outcome of the survey was found encouraging and construction of the plant started in 1980. The objective of this development project has been to promote dairy production in the irrigated plains and to ensure a reasonable milk supply.

The tenants union formed a cooperative whose membership is open to every livestock owner capable of supplying the plant with milk at a predetermined price. Ownership of the plant remains with the government, represented by the Gezira Board. The Board agreed to allocate 5,000 feddans each year for forage production in the four blocks and in the crop tenancies used prior to cultivation of wheat.

It was agreed that the dairy cooperative could purchase the plant on installment. Money retrieved through this purchase will be used to establish new plants in different parts of the scheme. The plant produces 6,000 liters of toned pasteurized milk daily (25% reconstituted milk, 3.5% fat) packaged in one-liter plastic containers for sale. The cooperative collected a net profit [illegible] early LS 100,000 in 1984.

Allocation of temporary forage tenancies

The amount of milk each tenant supplies to the cooperative determines the acreage of the forage tenancy. For each 400 liters in a 9 month period, the tenant receives 2 1/2 feddans up to a ceiling of 70 feddans. These forage tenancies can either be on the farmer's land (if he is a cotton tenant) or on another tenant's land. When the forage tenancy is allocated, a deposit of LS 10 feddans is required to cover cost of fertilizers and residue removal. The scheme made it a point that each tenant should fertilize the land twice. Twenty kg of N (as urea) is applied during the establishment phase of the fodder crop and again after cleaning, thus restoring soil fertility for the subsequent wheat crop. Forage sorghum (Abu 70) is sown during April and the first cut is harvested during mid-June with a second cut in July. Thus forages are available for the farmer during the critical months of the year during which the shortage of feeds is greatest.

Relationship between the dairy farmer and the Gezira cooperative

When a farmer applies for membership in the cooperative an initial interview and field visit are made by the members of the board of directors or their representatives. They assess the farmer's potential, location, and route accessibility. Even distant farmers have an opportunity to become cooperative members, providing that they transport their milk to the cooperative. Milk received from each tenant is weighed, checked against adulteration, undesirable odours and dirt. Milk records are kept by both the farmer and the cooperative. Each fortnight, members receive payment for their milk, minus any costs for services or loans.

The cooperative provides its members with free veterinary services, and sells drugs, salt licks, concentrates (cakes, brans, molasses) and the like, at cost. The cooperative also provides agricultural machinery services at a reasonable cost. Extension services are provided by the cooperative nutritionist and agronomists.

Initial research approach

A research team was formed to study dairy production systems in small holdings in Gezira Scheme. The team is composed of an animal scientist, agronomist, agricultural economist, veterinarian and dairy production graduate students. Initially a tour was made by the research team to 10 different villages of the farm blocks. The objective of the tour was to familiarize the team members with production systems. The team made occasional stops at randomly selected villages and conducted informal interviews with three to four farmers in each village. Farmers were interviewed regardless of whether or not they were affiliated with the cooperative, although a question about cooperative membership is routinely asked. Other questions seek information on livestock on owned, and whether they are kept in the village or sent away to pasture lands outside the Gezira.

It was clear from this tour that the major constraint to dairy production in the region is feeding. Feeds available are mainly crop residues. Few farmers feed concentrates and those who do limit themselves to brans and cakes because of the cost of alternatives. Feed shortages are especially critical in May through August.

Dairy cooperative members, interviews and analysis of data collected from cooperative records

Based on the outcome of the tour, informal interviews were held with randomly selected cooperative members. The interviews centered on the availability of feeds and the productivity of cattle. The outcome of the interviews showed that the feed shortage problem in May through August was partially alleviated by cultivation of forages during April and May, which would be ready for feeding in June and July. For other months, residues and concentrates are fed.

Analysis of the data revealed the following aspects of milk production:

Average amount of milk/farmer/month	702 ± 120 liters
high peak production	1199 ± 474
second peak	854 ± 65
lowest production	262 ± 130

The highest peak for 80% of the sample is in March when the cotton fields are grazed. The second peak coincides with the fodder harvest in June and July. There is sizeable variability between farmers within a village and across villages. This necessitates a more detailed survey on feed budgeting and on the presence of other livestock that share residues with cattle.

The survey

A more detailed survey was conducted on the selected farmers to gather more data on herd structure, methods of service, calving rates, mortality, feed, and other aspects of dairy production. The principal breed kept is Kenana, however, 5% of the farmers have crossbreeds. Table 2 shows various aspects of estimated milk offtake. Offtake is equal to production minus the amount left for the calf, which was estimated at 1.5 liters per day. About 20 to 30% of the milk produced is not delivered to the cooperative, but is used for the family or for sales to other consumers or to traders. About 80% of the farmers indicated that they were feeding concentrates, such as molasses, cottonseed cake, or bran. However, 20% fed only crop residues and green forage in June and July. The maximum production is reached in March when animals graze cotton fields and in July when green fodder is available. This substantiates the earlier analysis of the cooperative's records. Although 75% of the farmers keep sheep (4 to 70 head) and goats (2 to 30) only 25% of those admitted dividing green forages between all classes of stock and 5% indicated that they sell green forages to others. Therefore, the lactating animals are not fed adequately.

On-station trials

It was apparent from the preliminary data analysis that the Kenana have low productivity under farmer conditions. This is in contrast with the finding that this breed has a high potential for milk production (Boyns, 1947). Even under natural habitats, Kenana cattle produce a considerable amount of milk in spite of exposure to extremes of natural hazards (Hassan, 1968). Dahab (1966) reported that some Kenana cows gave 22.2 kg milk per day in experimental conditions. On the other hand, Osamn (1981) reported an average yield of 1860 kg in 222 days, or 8.4 kg/day. From those findings, it is clear that this breed has a good genetic potential for milk production which could be exploited under better management.

Average and maximum daily yield reflect the genetic potential of the herd and are greatly affected by climatic conditions. Osman (1970) reported 5.9 kg as a daily mean for the Northern Sudan Zebu, which includes the Kenana breed. From this discussion, and from observations gathered from the survey, an on-station experiment was designed to investigate milk yield of the Kenana breed, simulating farmers' conditions. Although it was observed that few farmers (less than 10%) use crossbreeds, differences between Kenana and Kenana x Friesan crosses are of concern since policymakers are trying to promote crossbreeds. Comparisons need to be made to produce data that can help farmers decide whether or not to accept interventions for genetic improvement (given their ability to fee cattle at different levels).

Materials and methods of the on-station experiment

Sixteen cows, eight Kenana and eight Kenana x Friesan crosses were selected for the study. Selection was made according to the cow's lactation numbers (e.g., third, fourth, etc.) which would be representative of the majority of cows owned by farmers. Four cows from each breed were in the third lactation and four in the fourth. Cows within a lactation group had similar calving dates. Animals were housed in two open sheds and were supplied with a feeder and a watering

trough. Cows were group-fed for 40 days in such a way that each cow received 20 kg/day for the Kenana and 30 kg/day for the crosses following a feed budget similar to that followed by a farmer. The concentrate mix consisted of sorghum grain (15%), wheat bran (38%) undecorticated cottonseed cake (35%), molasses (10%) in addition to Ca Co^3 (1%) and common salt (1%). Ingredients were mixed daily and fed twice a day at milking time. Kenana cows received 3 kg/day of the concentrates and the crosses received 4 kg/day.

In contrast to farmer practice, cows were hand milked twice a day without the presence of the calf. Direct comparisons were made of the breed effect on milk yield between Kenana and the crosses. Milk from individual cows was weighed and recorded; differences were so conspicuous that no statistical analysis was performed.

Within breed analysis of variance was employed to determine the effect of lactation on mean milk yield (Steel and Torrie, 1960). Table 2 presents the total and average daily milk yield of Kenana and the crosses during the experimental period. The crosses gave more milk than Kenana at both lactation numbers. The crossbreds gave 11.5 and 7.3 kg/day in the third and fourth lactations, respectively, while Kenana cows gave 5.4 and 4.4, respectively. Table 3 presents the analysis of variance of milk yield for Kenana cows in third and fourth lactations. Table 4 shows the effect of lactation number on the milk yield of the crossbred cattle. In both breeds, lactation number affected milk yield significantly ($P < .05$).

DISCUSSION AND CONCLUSION

Of the breeds under test, Kenana cattle produced less milk than the crosses, however, the crosses were fed slightly better. Homeyer and Heady (1957) stated that, regardless of ratio of concentrate to hay fed, milk producing ability is more important than the intensity of feeding, although feeding is important for exploiting this ability. Nevertheless, Kenana cows were able to produce a fair amount of milk under poor management. On the other hand, there are breeds of cattle

that express their milk producing potential better, and produce more, when kept under improved conditions (Hassan, 1968). Osman (1970, 1981) indicated that indigenous Sudanese cattle and other tropical breeds are known to be more resistant to high temperatures and to low levels of management and can perform well if management standards are improved.

It may be more rewarding to farmers to feed their local breeds well. Abdelatif (1984) studied the productive performance of Kenana and crosses from record analysis of the University of Gezira farm, and concluded that there is significant ($P<.01$) difference in milk yield between Kenana and the crosses in favour of the crosses. Average (4.7 kg) and maximum (7.4 kg) daily milk yields were lower than those of the crosses (6.2 and 11.1 kg, respectively). Dahab (1966) argued that when selection for more milk yield was imposed, Kenana cattle were able to produce up to 22 kg of milk/day. This raises a concern when breed comparisons are made.

Judging by the outcome of this experiment, Kenana may do well under existing conditions in small dairy farms in the Gezira. Economic analyses need to be done to put the production into better perspective. The study suggests that an urgent evaluation of the milking herd needs to be done in which old, diseased and low producers are culled and replaced. Those retained should be adequately fed and managed. Further, a sound plan for crossbreeding should be designed to evaluate the real economic benefits that can be obtained from the introduction of exotic breeds. Crossbred cows under poor management will not only produce less but could also be a cause of the failure of the dairy operation, increasing risks at the farmer level. The question that needs to be asked, is whether or not the farmer is ready to feed their cattle adequately, given their feed resources and the husbandry practices that are feasible.

Impact of the dairy cooperative on policy changes

The success of the Cooperative in increasing the cash flow of the Gezira Dairy Cooperative members and the evident contribution of the

Cooperative to solving the problem of availability of milk to consumers in the Gezira area has prompted negotiations with policymakers toward policy changes regarding integration of livestock in the rotation. The evidence presented to the policymakers concluded that milk production increased when the Gezira board devoted 5,000 feddans for forage production to the dairy cooperative members on a seasonal basis.

Increased milk production increased cash flow to the farmers with a concomitant improvement in standards of living and purchasing power which could be used to provide concentrate feeds. A sizeable improvement was witnessed in herd productivity, reduced mortality and overall condition. It remains to be seen whether forage and livestock production could prove to be compatible alternatives to cash crops, especially in areas of low crop production. The administration agreed to devote a block (out of 53 blocks) in The Gezira, and another in Mangil extension (out of 54 blocks), for forage trials.

It is worth mentioning here that integration of forages in the crop rotation was made possible by cutting down the area of each crop. In the Gezira, the new rotation comprises eight feddans each for cotton and wheat, eight feddans divided between groundnuts and sorghum (four feddans each) as well as an eight feddan fallow-rested area to be cultivated in cotton during the subsequent season. Should the trials prove to be successful, the administration will consider expanding the area under forages in the rotation.

Effect of the change of rotation on team approach to FSR

The new interventions--including forages in the crop rotation--will be monitored in randomly selected farms in Barakat block. Monitoring includes a comparison between yields of different crops, and between economic benefits from the new and old rotations in neighbouring farms. Adjustments will be made by comparing the yields of the current season with those of the previous season. Further, a survey will be made at the end of the season to evaluate the perception of the farmer of the new crop rotaton. The feeding strategies of the farmers who possess

livestock will be evaluated, as well as the impact of the new intervention on dairy production and flow of milk from the members to the cooperative and to the consumers in the region.

The team realized the need for a critical assessment of the following: 1) quantity and quality of feeds in different months of the year and their effect on animal productivity; 2) feeding strategies and the impact on milk production of keeping other stock; 3) appropriateness of the new intervention for various social patterns of livestock in the Gezira; and 4) socio-economic benefits of the intervention.

A survey will be conducted to collect information in such areas as herd structure, feed availability, feeding, other inputs to dairy production, animal performance (calving rate, mortality, production, etc.), new enterprises (e.g., selling sheep), and milk flow to the cooperative. This approach will concentrate on the initial group selected (four farmers from each of four villages from each of the four blocks). The survey will also include farmers within Barakat block in which the new crop rotation was adopted. In addition to the survey on-farm monitoring will be conducted to evaluate the cooperative's interventions such as molasses feeding, forage conservation, health aspects and supplementation. Individual farmers from the initial surveyed group will be monitored through closer observation of husbandry, milk yield, feed budgeting and other forms of livestock production in addition to dairy cattle.

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Table 1. Agricultural calendar and by products of each crop

Crop	Sowing date	Harvest	by-product
cotton	Jul/Aug	Jun/Feb	cotton stalks, leaves, and dropped cotton
groundnuts	May/Jun	end of Nov	groundnut straw
sorghum	Jul/Aug	Nov/Dec	sorghum straw (Gassab)
wheat	Nov	Feb/Mar	wheat straw

Table 2. Means and standard deviations of total milk yield and average daily milk yield of Kenana and the Kenana x Freisian cross, kg of milk

Breed	Lactation number	Total yield mean	Total yield s.d.	Daily yield mean	Daily yield s.d.
Crosses	third	446.9	46.2	11.5	1.5
	fourth	291.9	97.5	7.3	2.4
Kenana	third	217.1	10.0	5.4	0.2
	fourth	175.9	12.7	4.4	0.3

Table 3. Effect of lactation number on milk yield of Kenana cows

Source of variation	degrees of freedom	sum of squares	mean square	F
lactation number	1	21.85	21.85	3.37
error	6	38.85	6.48	

Table 4. Effect of lactation number on milk yield of Kenana x Friesan crosses

Source of variation	degrees of freedom	sum of squares	mean square	F
lactation number	1	35.5	335.5	18.60
error	6	108.2	18.0	

DISCUSSION

Q. How was milk marketed prior to the cooperative?

A. Milk was sold directly to the consumer. Now it is marketed by the cooperative and is of better quality which has improved other milk products.

Q. What was the source of the animals used in the dairy cooperative scheme?

A. Farmers owned cattle before the coop existed, both local breeds and some cross-breds. Traditionally they were left to graze on roadsides and scavenger on crop residues. In the dry season, they were moved out of the area. Farmers found that cross-breds had greater health problems than local animals. As a result, the local animals were preferred.

Q. You indicated that some of the fodder produced was being used to fatten sheep. Is that being monitored as part of the overall economic analysis of the project?

A. Some of the farmers indicated that milk sales were not their major objective. Calf production and sale were more important. The coop is considering a calf fattening center to relieve pressure on fodder supplies for individual farmers who should be concentrating on feed for pregnant and lactating animals. Sheep were not part of the agreement when the land was allocated to the farmers for fodder production, and their use of fodder is "illegal." Farmers are, therefore, less willing to provide information on sheep production. Data would have to be obtained by observation.

Q. Why is the University of Gezira conducting research and not the Ministry of Agriculture (MOA)?

A. The MOA has recently established a research station in Central Sudan. The University of Gezira had previously been a research site under the Ministry. Because the University is close and the project is responsible to the Central Government not to the MOA, it seemed complementary for the University to work with the central government since the Gezira scheme itself is under its control. However, the regional government is aware of the effort and is appreciative.

Q. When results of on-station trials were applied to farms, apparently the outcome was negative. Was an attempt made to find out why and whether one should redesign the trials to make the technology work under farm conditions?

A. On-farm trials failed because the feeding strategy on farms was entirely different from the trials approach. The farmers' approach was to feed all types of stock for survival during the critical summer season when forages are available and not merely his lactating animals as the on-farm trial attempted to do.

Q. What is the difference in price per liter of reconstituted milk as compared to the price paid to the farmer?

A. The reconstituted milk is almost half the price paid for farm milk. Only "tone milk" is sold by the cooperative.

Clarification: The actual output of the Gezira unit is 6,000 liters per day. This is made up from four or five thousand liters of delivered fresh milk to which a quantity of reconstituted dry milk is added to tone the final product. This also gives a degree of consistency of composition of about 3-1/2% butter fat.

Q. I believe that it is on the level of extension that one bases the evaluation of an innovation by using the degree of adoption of the technique. The mandate of ILCA stops at the pre-extension level.

By what means do you determine the pre-extension or extension phases?

A. I agree that the work we are doing with farmers is not extension per se. Between actual station research and extension, there is a need for pre-extension types of on-farm studies which have to be carried out by a researcher with the full involvement of the farmer and extension agent. This is the phase in which we are now. After this phase, the intervention is then ready for extension by national officials or agencies.

Q. You mentioned at the beginning of your presentation that the work you were going to report on was no "research as such." However, from the methodologies reported and the monitoring data collection described, I am of the view that your work is research. What do you think of this?

A. I agree with you. What I meant to say was that it wasn't "controlled experimentation," and not research.

Comments:

The following comment was made on milk marketing in Nigeria. Nigeria presents a different situation than Sudan or Ethiopia because there are many people (80 million) and few cattle (53 million). So there is a market everywhere even in the remote rural areas. There is a different local market in walking distance every day of the week.

The milk marketing system is very complex and subtle. Milk is sold as butter and sour milk. The sour milk is sold with cooked millet or sorghum which has a value added due to the cooking. The milk and millet are mixed and consumed on the spot.

The market accepts seasonal prices. A variable dilution using a plant additive as a thickening agent is often used. Thus, on a whole milk basis, prices can vary by five times from the wet to the dry season.

In this way, the household income is stablized throughout the year.

The urban dairies find powdered milk much cheaper and easier to handle than whole milk.

The government is determined to boost whole milk production but this is not easy to achieve because of the above factors.

Dairy cooperatives in Ethiopia do face maketing problems. Farms located near the urban centers enjoy the best marketing opportunities. Those in the Institute of Agriculture research are skeptical in recommending crossbred cows to the peasant sector, given the other pressing problems farmers have with the local breeds; so we are planning to follow a stepwise approach of identifying problems and design other interventions before launching a crossbreeding program for the peasant farmers.

Actually, the Government of Ethiopia is trying to introduce crossbred dairy heifers to cooperatives that have markets for milk. However, there are cooperatives that have started dairy production in areas far away from urban markets. As the number of stock increased, the marketing of milk has become a problem. Thus, the government has recently started introducing milk processing equipment (churns, cream separators) so that the cooperatives can process the milk into butter and cheese which are easily transported for long distances to markets.

USE AND ISSUES IN ON-FARM RESEARCH TO IMPROVE FODDER FOR LIVESTOCK OF AGRO-PASTORALISTS IN THE NIGERIAN SUBHUMID ZONE

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INTRODUCTION

On-farm research (OFR) is an integral part of farming systems research (FSR). FSR views the farm as a whole to study the various interactions in the systems and is normally carried out by multidisciplinary teams. In collaboration with farmers such teams evaluate the relevance of introduced technology to the intended users and their response to it. A farming system in any area reflects the rational use of the experience and resources of the farmers to attain their production objectives. The production goals of small farmers are generally determined by scarcity of capital, limited labour, and the need to avoid risks. Therefore their farming system cannot be influenced to produce rapid and drastic changes, no matter what may be the potential of a new technology. The chances of effecting changes in the farming system may be further reduced if the introduced technology involves new practices and inputs. OFR allows stepwise introduction of technology and its evaluation by a multidisciplinary team in the appropriate socioeconomic circumstances. This makes it a useful tool in the diffusion of a technology into a recommendation domain (OFR trials give a simple demonstration of a new technique). The new technique may then go back, if necessary, to the experiment station for further refinement. These points are illustrated in this paper by examples drawn from the application of OFR in the improvement of fodder for livestock of agro-pastoralists in the subhumid zone of Nigeria.

PREPARATION FOR OFR

Before OFR is begun, the prevailing production systems of the farmers will have been studied so that the impact of an introduced intervention can be measured against this. Timing of the OFR in overall context of FSR should logically follow diagnostic, descriptive and station-based

technology testing phases. However, in some instances, an existing knowledge of a possible intervention may favour OFR as the starting point and therefore it could be considered as a design activity to focus on a relevant problem for FSR.

For producers and policy makers alike, the under-utilized subhumid zone of Nigeria (190 - 270 days growing period and 900 - 1500mm rainfall) offers great potential for increasing human and animal population. It can also provide areas for relocating stock repeatedly threatened by drought. There is increasing evidence of more cropping and settlement of pastoralists around cropped areas in the subhumid zone of Nigeria (Van Raay, 1975; Agboola, 1979; Bourn and Milligan, 1983). This is favoured by tsetse control, both by spraying and land clearing.

Livestock are directly affected by the low quality of natural feed, particularly in the dry season (Figure 1). This is reflected in their slow growth (5 years for first calving), low calving rates (49%), and high mortality rate, mainly among calves (14.4%). Feeding 1 kg of cotton seed cake or grazing equivalent of 2 1/2 kg dry stylo (C.P 12%) per day helped to overcome dry season nutritional deficiencies and increased overall productivity of cows by 46.2% (Otchere, 1984). But agro-industrial byproducts cannot be an adequate solution due to increasing cost, limited and uncertain availability, and competition from alternate uses. A cheaper and renewable protein source such as a forage legume might be more appropriate, but forage legumes cannot be freely grown due to communal grazing and indiscriminate range burning. There is also the problem of land acquisition because land owners are generally crop farmers, not pastoralists, and there are no extra resources to grow legumes as well as food crops.

Possible ways in which forage legumes could be used to improve fodder in the subhumid zone are shown in Figure 2. Some knowledge of the usefulness and agronomy of forage legumes such as Sytlosanthes guianensis cv Schofield, S. guianensis cv Cook, S. hamata cv Verano, Centrosema spp was already available from previous work in the country. When ILCA began its work in the subhumid zone of Nigeria, however, this

was not being used by the pastoralists. Trials at the farmers' level were therefore begun to test the following hypotheses along the avenues proposed in Figure 2:

(a) Introducing a forage legume into the crop mixture should not be a problem because intercropping is already the most common practice.

(b) Pastoralists value crop residue grazing, and therefore prefer to settle near crop farmers. The farmers benefit from manure and may be willing to incorporate a forage legume in their crop mixtures to enhance the value of crop residues.

(c) Pastoralists would be prepared to grow forage, provided it requires little re-allocation of resources and that they can be sure their own animals will benefit from the grazing.

OFR for Improvement of Crop Residue

The nutritive value of crop residues from the major cereals is very poor. Animals tend to select more nutritious parts, such as immature panicles and leaves in the upper part of the stem, much earlier in the dry season, following grain harvest, but these make up only a small fraction of available DM (Powell, 1984). Nitrogen content of stylo was found to be above 1.8 percent (C.P. 11.3%) during most of the dry season and therefore could increase the overall protein level of a low quality fodder.

The first ILCA activity in fodder improvement involved sowing S. guianensis cv Cook and S. hamata cv Verano under sorghum in farmers' plots. Farmers were not required at this stage to contribute anything except their permission to use part of their cropped area. All cultural practices for the crop were carried out as usual by the farmers. Stylo was new to the area and farmers could not differentiate it from weeds. Therefore stylo was weeded out in spite of cautioning against this. One of the agro-pastoralists who failed to weed the crop

suffered substantial loss of grain but cordoned off the area sown to stylo after grazing crop residue to encourage stylo regeneration in the following season.

Subsequent attention was needed at the experiment station on the difficulties farmers had in incorporating stylo into grain crop mixtures. This involved spatial and temporal adjustments of crop-forage components in a mixture. Time of sowing stylo under sorghum was found to be critical, and specific to legume type, if one was to derive optimum grain and fodder yields. Planting S. hamata three weeks after the sorghum and S. guianensis six weeks after the sorghum caused minimum grain yield reductions and increased the nutritive value of available fodder (Table 1). Trials that varied crop combinations and densities revealed the possibility of growing S. guianensis with the mixture of sorghum and soybean. Traditionally, sorghum and soybean are planted alternatively on the same ridge (Figure 3B). But a pair of sorghum stands on ridges at 0.3m apart alternated with a ridge of stylo (inter-row sowing Figure 3E), offered a good compromise for growing a two-crop/one-forage mixture without affecting adversely the grain yields, while significantly improving fodder quality. Subsequent on-farm trials tested under-sowing and inter-row sowing of stylo in sorghum under researcher-managed farmer-executed conditions. In most cases, these confirmed that the quality of fodder could be substantially improved without causing grain reduction.

A major problem in conducting on-farm trials was the difference in inputs and lack of synchronisation of various crop husbandry practices by the cooperating farmers. Seeds for planting are saved from the previous season. Due to phenotypic and genotypic variations in the same crop yield results between farmers could not be strictly compared. So for uniformity, certified and genetically pure seeds had to be supplied to all cooperating farmers in subsequent trials. Time of ridging, time of planting, and rate of fertilizer application, time of weeding etc., varied among farmers. Researchers could not have full control over these operations especially in trials that were entirely farmer-managed and farmer-implemented (Powell 1984).

Undersowing (sowing a forage legume in every cereal row after its establishment) and inter-row sowing (cereal and forage legume planted in alternate rows) are simple techniques for improving fodder. But pastoralists who adopted these techniques encountered different problems. Although undersowing improved fodder yields, the pastoralist could not produce sufficient good quality fodder for an average herd of 50 head because the cropped area did not exceed 0.5 to 1 ha at any time. Where livestock and crop enterprises are in different households, as in Abet (Kaduna State), farmers could not be motivated to include stylo into the maize, sorghum, millet, soybean mixtures, merely for the benefit of cattle. But farmers were willing to grow stylo if the improved fodder or its seed was marketable. In the case of inter-row sowing, it was difficult to see the logic of labouring on ridge-making if only one out of two ridges was to be used for the cereals, even though at the research station experiment the stylo was found to be more productive on ridges than flats (Mohamed Saleem, 1984).

Techniques of undersowing and inter-row sowing into similar crop mixtures as in Abet were found to be more acceptable in Ganawuri (Plateau State) which is an intensively farmed area where crop and livestock enterprises are in the same household. First year on-farm trials at Ganawuri, in 1984 for example, involved three farmers, but more farmers wanted to adopted the techniques in 1985.

Establishment of Fodder Banks

The widespread practice of communal grazing does not motivate pastoralists to grow fodder crops. It was hypothesised that techniques which guaranteed that the investors' animals would benefit from the improved fodder were more likely to be adopted. To achieve this, the idea of fodder banks - concentrated units of forage legumes, established and managed by pastoralists near their homesteads for dry season supplementation of selected animals - was put forward for on-farm testing. This involved the following guidelines:

a) Fencing a block of 4 ha. using metal or bush poles.
b) Preparing a trampled and manured seed-bed by confining herds overnight in the area before onset of rains.
c) Broadcasting warm water scarified seeds mixed with 150 kg/ha of single superphosphate.
d) Controlling fast-growing grasses through grazing early in the season.
e) Allowing forage to bulk up by deferring grazing until the dry season.
f) Use of the fodder bank by selected animals according to determined stocking rate for 2.5 hours per day during the season.
g) Ensuring sufficient seed drop and stubble for regeneration in the following season.

Following these guidelines under researcher-managed conditions, it was possible to produce good quality fodder annually (Table 2) to supplement the most responsive animals (15-20) in an average herd during the dry season. However, compliance with and response to these guidelines were different when the trails were managed by the pastoralist.

Preparation of land by confining animals during the dry season was inconvenient to some pastoralists because it conflicted with manuring of farmers' croplands for cash. Seedbed preparation early in the wet season could not be completed for planting in the same season due to the limited time and various number of animals in the herd. Also, that is the period when pastoralists manure their own crop fields. Since an average herd of 50 animals in a period of three nights (within which they are confined during the night at the beginning of rains), could only trample 0.06 to 0.6 ha properly it was not possible to trample 4 ha in time to establish a forage legume stand during one growing season. However, pastoralists with large herds or who could mobilize other herds were able to complete preparation of 4 ha during one season.

Concentration of Legume in Fodder Banks

Stylo is slow growing compared to grasses. As fodder bank management aims at concentrating on the sown legume, competition from other species needs to be reduced. Grazing behaviour studies have revealed that cattle selected grasses in preference to stylo at the beginning of the rainy season. Wherever this could be applied on experimental fodder banks under complete control of the researcher, grasses were successfully controlled, which resulted in a higher stylo composition in the total available fodder at the end of the season.

Pastoralists who established fodder banks on animal-kraaled areas, however, objected to early grazing because they feared worm infection in cattle from the relatively fresh dung and urine, and also because cattle will not graze in such areas due to the offensive smell from the excreta. Other pastoralists objected to early grazing for fear of young seedlings being trampled and killed, or that there might not be enough bulk left at the end of the growing season for the cattle to use in the dry season. In such cases, the unchecked grass growth smothered the stylo. Where the farmers established fodder banks using the same technique at Ganawuri, they did not object to their cattle grazing early in the season. It appears that for varying preferences, different land preparation techniques have to be developed. Pastoralists who have access to tractors have used them in land preparation.

Grazing Fodder Banks

Supplementary feeding of cattle with 1 kg of cotton seed cake (C.P. of 30%) made up for the nutritional deficiencies of Bunaji cows (Otchere, 1984). Based on this, it was hypothesised that cattle having access to about 2 1/2 kg of dry stylo (C.P. of 12%) could derive an equivalent benefit. On this basis, a 4 ha fodder bank could only support about 15 to 20 animals. It was therefore decided to select the most responsive animals such as lactating and pregnant cows. It was also assumed that

grazing the fodder bank for 2 1/2 hours in the evening would ensure that it was used in addition to normal grazing. However, management of fodder bank grazing varied greatly among pastoralists. Researcher's rationing of the fodder bank to selected animals was found to be illogical as all the animals in the herd are important to the owner, who wants all of them to benefit. Survival feeding is also found to be widely practised among pastoralists, contrary to earlier assumptions. There is also the widely held belief that pastures cannot be damaged by grazing. Some farmers even preferred to graze the fodder bank early in the dry season when the herbage quality is high, in the hope of improving animal condition so that they could tide over the dry season. However, most of them preferred to defer grazing until the mid- to latter-part of the dry season and go after crop residues in the early part. Grazing of fodder banks in the evenings was found to be difficult for some, especially those who are short of labour, as this required physical separation of the selected animals from the herd. Therefore, they changed the time of grazing. The herdsmen often need to keep the animals near the camp in the morning before taking breakfast or finishing other chores on the farm or in the compound. Putting the cattle into the fodder bank conveniently allowed him to do these things, knowing that the animals could not stray and that his small child or wife did not have to look after them. Also, pastoralists encountered difficulties in restricting grazing to 2 1/2 hours daily. Grazing for longer periods every other day or once in three to five days was adopted. Both options are at variance with the fodder bank guideline in respect to timing of grazing.

Regeneration of the Fodder Bank

The lifespan of a fodder bank is an important consideration for the investor. In order to protect the fodder banks from fire, pastoralists had to make fire breaks. Hoeing even a 1 m strip around the fodder banks was a time consuming and laborious operation. The technique of burning back was found to be simpler. But there were instances when it got out of control and part or all of the fodder bank was burnt. In some of the on-farm fodder bank trials, fire was started inadvertantly

from inside. This reduced regeneration from stumps of perennials such as S. guianensis and probably softened seed lying on the soil surface; this makes it less likely that the seed will survive the erratic rainfall pattern in the subhumid zone, as most seeds germinate after the first rain and die off during subsequent dry spells.

High stocking rate and very early grazing as practised by some of the pastoralists also affected regeneration. Grazing a S. guianensis fodder bank by the entire herd in its first year of establishment before seed set completely eliminated the legume in the 2nd year and it therefore had to be replanted. Although higher stocking rate and prolonged grazing reduced the seed reserve as the animals licked the soil late in the dry season, S. hamata fodder bank did not seem to be affected after its first year.

CONCLUSION

Livestock development programmes in Nigeria have so far suffered not from want of interest, ideas or materials but from misplaced strategies. Creating grazing reserves and strips, and over-sowing of legumes with a view to improving nutritional quality in no-man's land did not provide sufficient inducement to make the pastoralists settle, as had been expected. However, in their own time, they were settling anyway for various other reasons. The rate and degree of change that were expected in return for government investments, did not match the conditions and rate at which pastoralists were willing to change.

In the subhumid zone of Nigeria, nutritional deficiencies, particularly in the dry season, have long been recognised as a major constraint for livestock. But the livestock owners have never been in the habit of growing fodder. Now more than 50 fodder banks and up to 10 fields of cereals under-sown with stylo are spread in different parts of the country with prospects for more. Most of the fodder banks are funded by the livestock owners themselves.

We have learned through OFR that pastoralists are willing to change,

and to adapt a new technology to suit their own resources and convenience. OFR has also been helpful to: a) delineate target groups appropriate for a given technology as evidenced from the ready acceptance of including stylo into grain crop mixtures by farmers with livestock as opposed to farmers without livestock, and b) refine technologies from problems identified at the producer level to make them more flexible for wider adoption.

Preliminary indications are that improved fodder, particularly in the fodder banks, has improved cattle performance and reduced mortality in the herd during the dry season. As those pastoralists who own fodder banks are making arrangements to expand them, and others are wanting one established, more information is emerging from OFR. Although a long time-scale is needed to realise the full benefits to livestock, efforts so far made towards fodder improvement in the subhumid zone of Nigeria have been worthwhile.

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Figure 1. A generalised productivity pattern of natural herbage at Kachia Grazing Reserve.

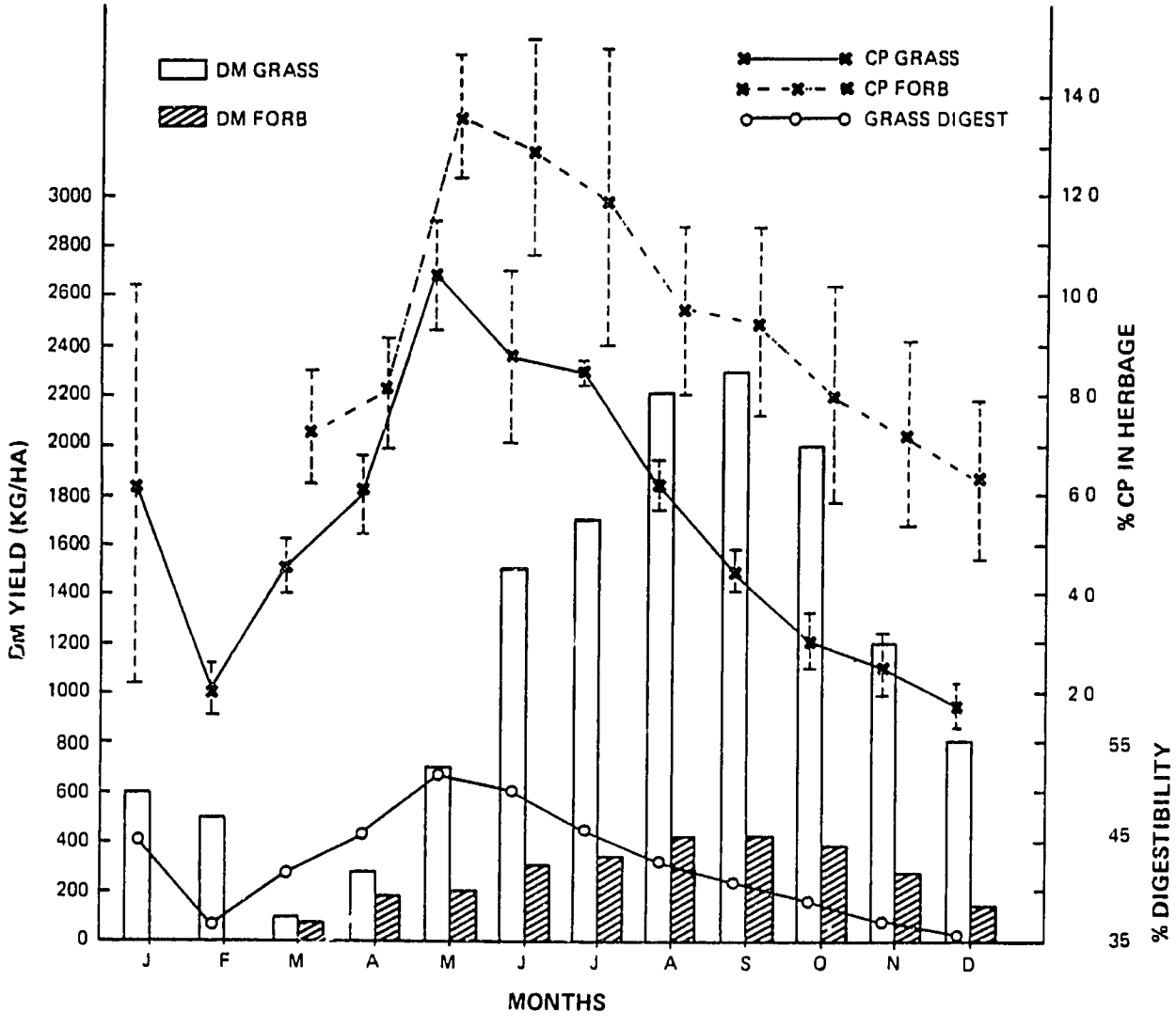


Figure 2. Possible use of forage legumes for fodder improvement in the Subhmid Zone.

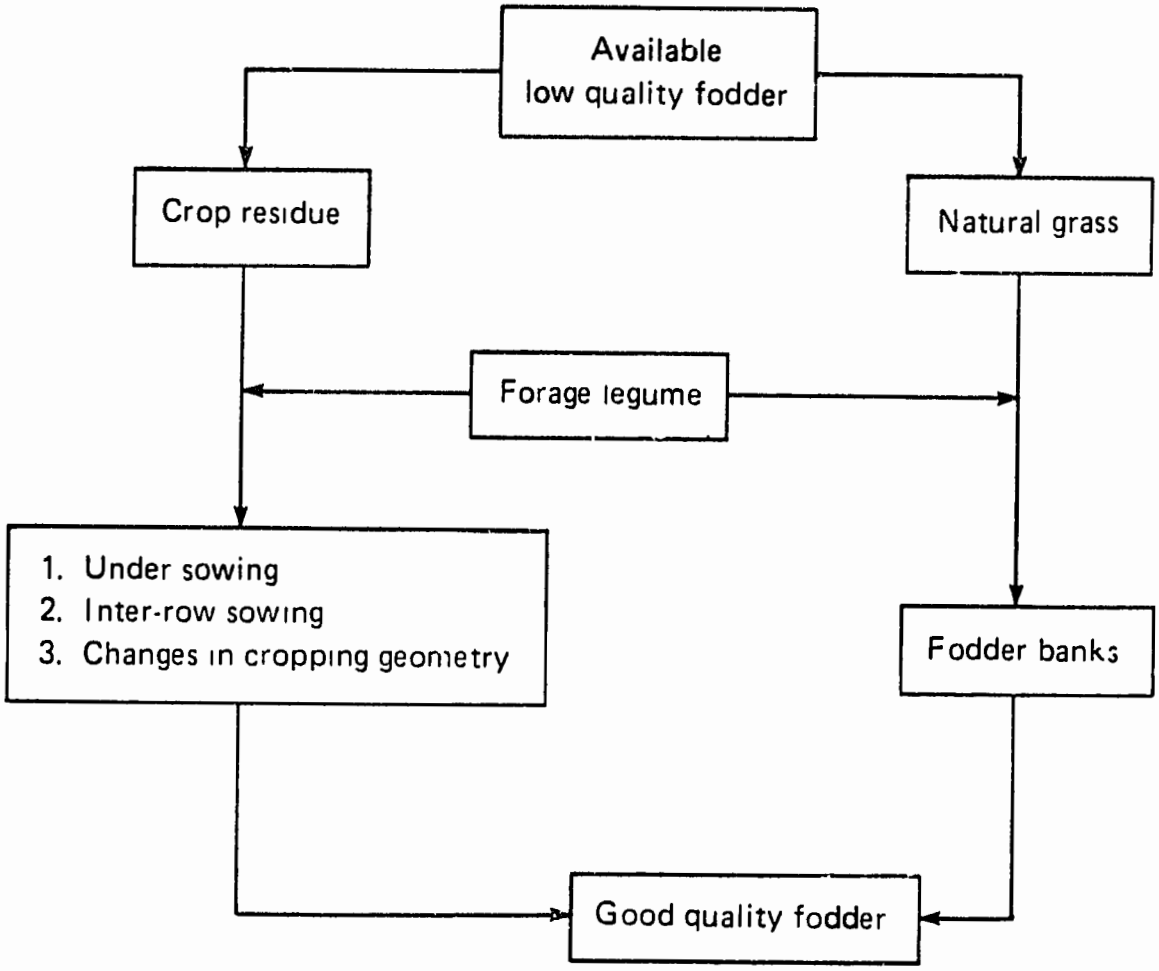
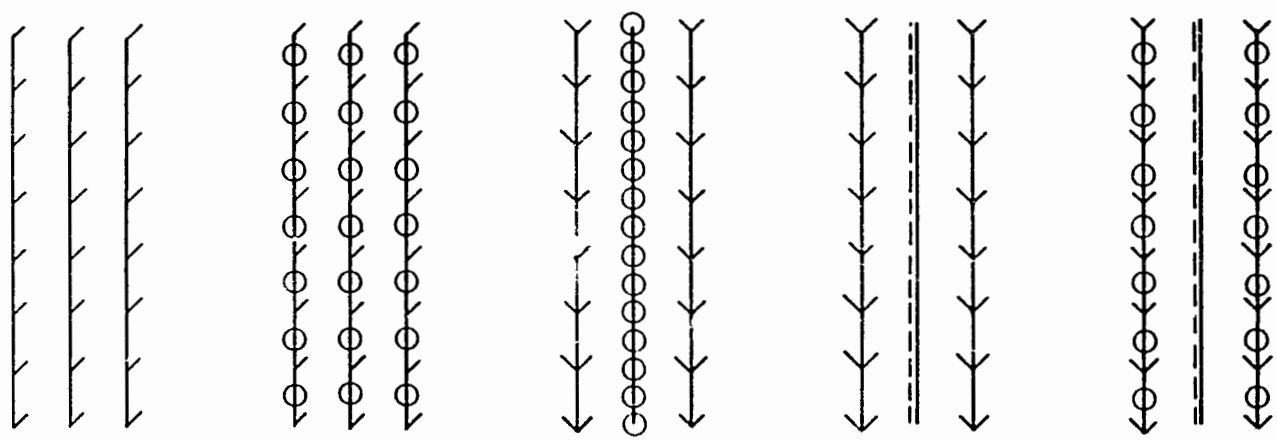


Figure 3. Effect of crop geometry on grain and fodder yields of Sorghum - Soybean - Stylo mixture.



YIELDS		A	B	C	D	E
GRAIN	sorghum	1491	1201	1558	1390	1331
kg/ha	soya	—	91	112	—	68
FODDER	sorghum	6159	5170	5549	5262	4813
kg/ha	stylo	—	—	—	1803	1360

Table 1: Effect of Undersowing Stylo on Grain Yield of Sorghum and Total Available Fodder

Stylosanthes Sowing Date	Grain Yield	Crop residue-	Stylo DM	Calculated DCP in Total fodder	Available CP kg/ha
	kg/ha				
		Unimproved Sorghum and Stylosanthes Hamata			
Sole Crop (CO	1226	7503 (2.4)*	na	-1.09	180
With Crop	357	1303 (2.5)	4010 (11.4)*	5.02	490
After 3 Weeks	1224	3719 (2.0)	1729 (12.0)	1.78	281
After 6 Weeks	1287	4260 (2.2)	702 (12.0)	-0.19	179
After 9 Weeks	1240	3919 (2.3)	408 (12.8)	-0.28	142
		Improved Sorghum and Stylosanthes Cook			
Sole Crop	2192	8796 (2.9)	na	-0.64	255
With Crop	480	2367 (1.4)	4334 (12.9)	4.66	592
After 3 Weeks	1550	3524 (1.6)	3215 (13.6)	3.34	493
After 6 Weeks	1918	5385 (1.4)	2464 (13.8)	1.42	415
After 9 Weeks	1980	7463 (2.9)	456 (14.7)	0.01	283

* Values in parenthesis indicate actual % CP in the respective fodder.
- DCP (Digestible Crude Protein) = 0.899 CP - 3.25

Table 2: Dry Matter productivity (kg/ha) and Stylosanthes composition (%) of fodder banks at the end of growing season at the producer level.

Location	Age of Fodder Bank in years				
	1	2	3	4	5
Kurmin Biri					
Total dry matter	6101	4191	5742	5006	5784
Weight of Stylosanthes	60	69	63	52	53
Abet					
Total dry matter	4281	4900	5278	5469	4789
Weight of Stylosanthes	58	63	65	70	71
Kachia					
Total dry matter	7111	5278			
Weight of Stylosanthes	68	65			
Kontagora					
Total dry matter	6120				
Weight of Stylosanthes	52				
Ganawuri					
Total dry matter	7900				
Weight of Stylosanthes	60				

Note: Plots were sampled in late October.

DISCUSSION

Q. Why is it possible that the crop area can be increased from a maximum of one hectare to include an additional four hectares? What limits the cultivated area with and without fodder banks?

A. The main constraint is labor. The area planted to sorghum is limited by labor for cultivation. Land preparation for fodder banks is done by animals penned at night. No additional herding labor and no conflict with sorghum production is experienced.

Q. How do you cope with the changing feeding strategies of the pastoralists in designing and interpreting your research findings?

A. By having enough replicates. One has to live with such problems, as differences between farmers are numerous. All one can hope for is a reasonable package that one can test on a number of farms. The package relates to the most urgent problems whose priorities were determined during on-farm testing.

Q. Have you tried using incentives in the form of farm inputs (fertilizers, seeds, etc.) in order to convince the farmer to do exactly what you want?

A. Care must be taken in the use of incentives. It might lead to over-expectation by the farmer.

Q. Did you conduct any of your research on a research station or on your fifty hectare farm?

A. Yes, we did some trials on varieties, etc. on the ILCA farm which was established in the area. We tested the best interventions on the farms and we worked both station and farm tests together.

Q. Did you use government stations to do your research on?

A. No. There are none in the area, but there is government owned land around the station on which testing is being done. Some of ILCA's interventions, like use of stylosanthus are observed on some of the government land.

Q. Are there fodder banks in both farm and pastoralists' areas?

A. Yes. They were started on farms by undersowing and then moved to pastoral lands where one crop is common. Both systems are going parallel.

Q. How do you perceive your "system" under investigation, as a single encompassing complex or as a collection of "sub-systems?" How are the limits defined?

A. We perceive four systems and defined them according to land use.

MATCHING THE IMPOSITIONS OF THE FARMING AND RESEARCH SYSTEMS AS A PRELUDE TO FARMING SYSTEMS RESEARCH

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INTRODUCTION

The performance that can be obtained from an auto is not just a function of the vehicle's specifications. It also depends on the mechanic's skill, experience and equipment. An analogy can be applied to Farming Systems Research (FSR). The literature, however, concentrates on methods for determining and removing constraints in farming systems but pays little attention to constraints in the research system or how the two sets of constraints interact.

FSR is targeted to serve the needs of farmers who are ordinarily cautious about technical change. This sets a conundrum because FSR is usually led by scientists who, in contrast to the farmers, usually have little prior experience in the research area and bear none of the risk inherent in adopting new technology. The FSR teams are expected to devise, rapidly and cost effectively, interventions that will be adopted by farmers with consequent significant improvements in farm productivity and income. The conundrum is expected to be resolved by the application of FSR organisation and methods.

A first priority is to identify constraints in the farming systems so that researchable issues can be identified and research proposals prepared. However, before that can be done some major decisions will have to have been made. Amongst such decisions will be major issues such as budget ceilings, team composition, time frames, etc. Since such decisions can have long-lasting effects on FSR implementation, the research sponsors should make a prior assessment of how proposed FSR programmes and target farming systems are likely to interact with each other. This would increase the understanding of what can be reasonably expected of a particular team in particular environments.

There is a host of literature on various ways of determining constraints in farming systems (Lang et al., 1984; Norman, 1980; Butler, 1984; Gilbert, 1980; Shaner et al., 1982). This paper concentrates on the possibilities and advantages of considering the constraints imposed on the conduct of FSR through the interaction of the research and farming systems and advocates an appraisal of them as a prelude to FSR.

Case Study

Since ILCA cannot mount research programmes in each nation of sub-Saharan Africa it has adopted an ecological zone approach. There are currently six field programmes; Highlands, Humid Zone, Subhumid Zone, Arid and Semi-arid, Ethiopian Rangelands and Kenya Rangelands.

The author's experience has been with the Subhumid Zone programme which was the last initiated, in 1978. The Subhumid Zone extends from Senegal eastwards to the Central African Republic and southwards to Angola and Mozambique. It covers five million square kilometers, equivalent to about 23% of sub-Saharan tropical Africa. Cattle are the dominant livestock species with an estimated 33 million head against 14 million sheep and 20 million goats (Jahnke, 1982). The zone receives from 900 to 1,500 mm of annual rainfall and has a growing season of 180 to 270 days each year. The productivity of cattle in the zone is low, mainly due to poor dry-season nutrition. The Programme therefore aims to increase cattle productivity through improved feed availability obtained by exploiting the complementarity of legume forage and food crops.

ILCA's interest in the zone was stimulated by the prospects for achieving a significant impact from research because, despite being of higher than average agricultural potential, the zone was relatively under-utilised. This perception was supported by the fact that, because of the pressures in the neighbouring humid and semi-arid zones, it was becoming increasingly rapidly occupied by cultivators and livestock owners. ILCA estimates that there are 4.5 million cattle in

the Nigerian Subhumid Zone (Bourn and Milligan, 1984) as opposed to the conventional figure of just 2 million (Jahnke, 1982). Another attraction was that the zone had formerly received much less attention from researchers than the other zones.

Although the FSR paradigm had been enunciated by Norman in 1976 (Institut d'Economie Rurale, 1976) and was fast accumulating published literature, ILCA chose for a while to use its own terminology, but in practice it adhered quite closely to conventional FSR philosophy.

The programme started with sociological and ecological reconnaissance studies, selection of case study areas and a state-of-knowledge symposium (ILCA, 1979). The prime conclusion of the state-of-knowledge symposium and ILCA's reconnaissance studies was that ILCA should concentrate on seeking means of enhancing the welfare of livestock owners through improved ruminant nutrition. It was recognized that it would be necessary to find ways for the livestock owners either to produce or have access to improved forages because there were not enough feedstuffs in the country and competition was bound to increase from monogastric enterprises and agro-allied industry. There had been over thirty years of pasture research in Nigeria and several varieties of forage legumes had been identified and tested, particularly at the National Animal Production Research Institute (NAPRI). ILCA was able to use these and the advice of NAPRI scientists in formulating research propositions. There had, however, been very little uptake of forage production off the research stations, and ILCA's first task was to devise practical ways for pastoralists and mixed farmers to incorporate forage legumes into their farming systems.

ILCA has taken two main approaches to achieving the above ends. It has developed techniques, described below, for establishing forage legumes on fallow or bush land. It has also conducted research on ways of incorporating forage legumes into cropping systems. The latter approach could be as important to cropping as to livestock production in view of the increasing land pressure and spiralling fertiliser prices.

In the course of the FSR work, the team also gathered a significant amount of information that has been employed in government policy formation (Federal Ministry of Agriculture, 1981), project formulation and development of extension services. NAPRI is also using the acquired experience in establishing its own livestock systems research team and in research policy.

The approach taken fits well with the standard outlines of FSR and involved three major efforts:

1. The determination of the productivity of cattle under the prevailing management systems and the responses due to improved nutrition.

2. The design and testing of techniques for establishing, maintaining and utilising forage legumes with the livestock owner's own resources.

3. The understanding of the socioeconomic circumstances of the target beneficiaries as they affect the likelihood of the proposed interventions being adopted.

The research is concentrated near Zonkwa in southern Kaduna State, Nigeria, in three case study areas: Kurmin Biri, Abet and Ganawuri. They respectively represent areas with predominantly agropastoral settlement, intermixed settlement of agropastoralists among arable farming comunities and mixed crop/livestock farmers. These are the major land use systems found, but not usually all adjacent, across the Subhumid Zone of West Africa. There are also some pastoralists in neighbouring Abet who have acquired certificates of occupancy to larger tracts of land and have, of their own accord, adopted interventions developed by the Subhumid Programme and have been included in the studies. These areas of contrasting land tenure provide convenient sites for comparing the suitability of alternative interventions in differing situations of government assistance, intensity of arable

agriculture and mixed and agro-pastoral livestock production systems. At the same time they have many common externalities such as market forces, government policy and seasonal effects that tend to confound comparisons drawn from distant case studies.

ILCA's original intention of looking at the problems of the zone as a whole dominated the early design. Thus a zonal-wide study was undertaken to find case study areas that would enable the study of livestock production under: high and low trypanosomiasis challenge; high and low intensity arable cultivation rates; and pastoral sedentarisation, with and without government assistance. This led to the selection of case study areas several hundred kilometers apart which turned out to be quite impractical. The ultimate concentration on adjacent but contrasting case study areas has proven to be much more pragmatic.

WELFARE CONSIDERATIONS

The object of any agricultural research is to improve the economic and social welfare of a particular target group of farmers and/or livestock producers.

Economic Welfare

A measure of the economic worth of an investment is the net present value of the incremental net income stream, discounted at appropriate rates of interest. Discounting is necessary to allow for the fact that money is of less value the later it is earned or spent and, therefore, allowance has to be made for differences in cash flows generated by the investments that are being compared. An investment that has a positive net present value at 15% is normally considered satisfactory in Nigerian agricultural economic appraisals. It is higher than the opportunity cost of capital, but necessarily so given the high risk of agricultural ventures not achieving their forecast benefit streams. Some economists prefer to use the Internal Rate of Return (IRR) which is the highest discount rate that the project cash flows can be

discounted without yielding a negative present value. The investments can then be ranked in order of their IRR's. In practice it is not a very useful measure in agricultural projects because it gives no sense of scale since all the present values are equal at zero. For example, a single cattle dip would almost certainly yield a higher IRR than a full farm project; but that is hardly a useful comparison. In FSR, with more than one product, aimed at a number of agencies, and possibly useful in several countries across an ecological zone and possibly even in neighbouring zones, it is difficult to estimate the potential value of the research. Therefore, if the full costs of the research can be discounted against an estimate of the likely uptake of just one intervention and still give a positive rate of return, that may be considered a very encouraging result. This conclusion will be further supported if the intervention also meets another rule of thumb criterion: Farmers are likely to be willing to adopt any practical intervention that promises to raise their net incomes by 20% or more.

Social Welfare

People are not only interested in economic gains. They are interested in interventions that make them feel more secure. They will also be interested in raising their individual and group prestige. Even though it is difficult to quantify such factors, they are important and must be evaluated in order to be able to devise appropriate inteventions. For instance, an intervention that is likely to promote inter-ethnic-group antagonism must be questioned very seriously, and is unlikely to be adopted as a suitable package for extension, irrespective of its economic merit.

Target Group

The cummulative economic merit of a particular intervention is a function of the size of the population potentially involved in adopting it and the adoption rate. In other words, the best intervention is normally one that is suited to a wide cross-section of a large community of farmers. There may also be spin-off benefits for other

communities. ILCA has evidence that forage legumes can improve soil nitrogen and carbon, improve soil moisture penetration, lower surface temperatures and decrease bulk density resulting in improved crop yields (Mohamed-Saleem, 1984). Even if primarily aimed at livestock producers, the introduction of forage legumes could benefit crop farmers if the two systems are adequately integrated (FAO, 1984).

The selection of forage legume introduction as the prime topic of research restricted the target population to settled pastoralists and mixed farmers. However, van Raay (1975) indicated that about half the pastoralists were at least semi-settled. This trend has continued (FAO, 1984) and current estimates are that there are 4.5 million cattle more or less permanently resident in the Subhumid Zone of Nigeria as against former estimates of 2 million (Bourn and Milligan, 1984). With an average herd size of 50 head, that implies that the target group is comprised of the owners of 90,000 herds of cattle. At an estimated 1.3 heads of household per herd, that amounts to 117000 households. There is no available estimate of the number of mixed farmers in the zone, but there is reason to believe that it is significant and growing.

FODDER BANKS

The first farmer ready package developed by the ILCA Subhumid Programme was legumes based (Stylosanthes) fodder banks (Mohamed-Saleem, 1984a). The fodder banks are units of about 4 ha of concentrated high quality forage legumes that can be established and managed without any mechanical implements. The seed bed preparation and weed control can be done entirely by grazing cattle. The fodder banks are aimed at producing sufficient feed to supplement the poor quality diet available from natural range and fallow land.

It was not until 1984, the fourth year of the programme, that enough fodder banks were established to provide meaningful statistical data, and there still has not been time for a final evaluation. However, on the best estimates available, the fodder banks will comply with the economic criteria discussed above.

The following figures have been extracted from cash flow analysis tables of a fo r bank simulation model developed for appraising fodder banks (k ann, 1984b). The model is driven by a herd growth model employing cattle production parameters obtained from herds monitored by ILCA. However, the qualification, mentioned above with respect to the nonavailability of sufficient time series data should be borne in mind. The costs and benefits pertain to the establishment a 4 ha fodder bank capable of supplementing about 20 head of cattle from the end of crop residue grazing in November to the early rains in March. The 20 head would normally include the breeding females and distressed animals from an average herd of 50 head.

The capital costs include fencing, seeds and fertilizer. Capital Cost = 2952.00 Naira(N). As a practical indication of what such an expenditure entails with respect to the herd owner's assets and income, 2952.00 N is equivalent to:

3.28 adult bulls
or 12.62% of herd value
or 100.33% of annual livestock sales

The impact on earnings can be judged by the following criteria:

predevelopment gross income	N 4790
predevelopment net income	N 3211
increase in gross earnings	N 2117 or 44%
increase in net earnings	N 1148 or 24%
increase in crop income (1000kg/ha on 1 ha rotating in the fodderbank)	N 400
1/2 value of two animals saved from sale in extremis	N 800
Total incremental income	N 2348 or 49%

Net present value	@ 10%	@ 15%
increased cattle productivity only	N 619	N -508
Total incremental net income	N 6992	N 4426

Note that fodder banks can be justified on the 20% incremental net income (or 15% plus internal rate of return criteria) by their use in preventing the forced sale of distressed animals. Though known for stylo pastures in Australian semi-arid regions (AMRC, 1984), this use had not been predicted and was actually discouraged in ILCA's original recommendations for the use of fodder banks.

There has been a positive response from livestock owners from both settled agro-pastoralists and mixed crop/livestock farming communities. The adaptability of the package to different ecological and socioeconomic environments is also very encouraging, but it is still too early to pass any final economic judgment because it will be necessary to obtain more time series data on uptake, utilisation and production responses.

To test the effectiveness of FSR, the research costs have been discounted against the cummulative net cash flow of only existing and officially proposed fodder banks. This ignores the possibility of fodder banks being established by private initiative or with the help of other agencies such as the River Basin and Rural Development Authorities. It also does not take into account the other products of FSR alluded to above.

The Government of Nigeria initially proposed implementing 4,000 fodder banks but, if only the 2,000 presently proposed for the Second Livestock Development Project are implemented, the research investment should have a greater than 5% IRR on the basis of improved livestock off-take alone. If the value of salvaged animals and improved crop yields is added, the estimated IRR exceeds 15%. The costs of extension were not incorporated in order to retain simplicity and because fodder banks are proving to be an aid to general extension. They are foci for extension activity that has been lacking since the success of the veterinary campaigns against rinderpest and contagious bovine pleuropneumonia.

The benefits of utilising the fodder bank intervention to improve the

rate and extent of soil regeneration of fallow land are begining to be perceived by local communities. This could eventually yield even greater benefits in terms of increased production, saving of fertiliser costs and improved harmony between cultivators and livestock owners who are typically in different but neighbouring communities.

In a situation where herds are made up of animals belonging to different individuals, where the various animal products interest different groups and the land on which the forages are expected to be grown belong to yet another group, the social factors are bound to be complex and the benefits difficult to determine. Thus the reasons for adopting fodder banks include enhanced prestige and security (Taylor-Powell and Suleiman, 1984). In Abet, where pastoralists are settling amongst cultivators, they have not been allowed to establish more than the original four fodder banks. This constraint may be overcome if the ability of forage legumes to raise the cropping potential of the local soils (Mohamed Saleem, 1984 b) can be exploited by suitable techniques for cropping on fodder banks.

IMPOSITIONS

As indicated above there are impositions on both the production system and the research system which affect the conduct of FSR and which should, therefore, be considered in the financing and management of FSR programmes. The following sections discuss a few such impositions with illustrations drawn from ILCA's Subhumid Programme. The links between the impositions and the achievement of welfare benefits amongst the target group of farmers and livestock producers are summarised in Figure 1.

IMPOSITION OF THE PRODUCTION SYSTEMS

The following is not an exhaustive list. The particular impositions were selected as illustrative examples and because they tend to be different in their effects in FSR involving livestock as opposed to purely cropping systems.

Farmer Scepticism and Independence

Farmers always tend to be sceptical about change promoted by third parties and this imposes restrictions on the ambitions of FSR scientists. The effect is more pronounced when, as in the case study areas, the farmers have been exposed to failures of previous schemes and services. To counter this the ILCA FSR team took pains to get to know the farmers with sociological and grazing behaviour studies before attempting any research that involved handling cattle or on-farm operations.

The jealously guarded independence of subsistence farmers is also a factor that must be taken into account in planning and implementing FSR. The less individualistic the farmer the easier it is to recruit and keep participants in the research programme. In the mixed farming case study area of Ganawuri participation was facilitated by the presence of a strong and popular chief. In the other case study areas recruitment not only took longer but larger numbers had to included in order to compensate for the greater number of dropouts. This was particularly true of pastoralists who could move their herds far from the research area.

Producer Goals

In the case study areas cattle are herded in units of about 50 head. These herds have a market value of about US$30,000. The gross income is about US$6,000 of which 66% comes from cattle sales (Waters-Bayer, 1984). Net income per herd from sales of livestock and livestock products is about US$4,200 which is equivalent to twice the urban minimum wage. Since the average herd supports about 1.3 heads of household, their consumption patterns are more modest than their capital holding might suggest. The men are responsible for the cattle welfare, purchases and sales, but women have the prerogative over the sale of milk products. The extent of cropping is for both the agro-pastoralist and mixed farmer, controlled by the availability of

labour, and is a first priority for additional labour. There is no restriction on grazing area and thus very low opportunity costs for keeping additional cattle. In view of currency inflation and low livestock mortality, increasing cattle numbers is an attractive investment. In such a complex situation, interventions had to be found that aroused the minimum of conflict between the different goals. Some obvious interventions such as culling poor stock and early weaning of calves had to be ignored.

Farmer Spatial Distribution

Because cattle need large areas of grazing, the herds tend to be widely spaced. If, at the same time, the research is intended to concentrate on only the breeding females and young stock, the effective numbers will only be about 20% of the herd, and adequate samples can only be drawn from even wider areas. Conducting research over large areas is obviously more costly and prone to problems of supervision which must be accounted for in the FSR proposal.

Producer Resources

The main resources employed in farming are land, labour, capital and management. The varying land tenure arrangements that occur across Africa can lead to quite different rankings in the suitability of different interventions. Where the prospective beneficiaries do not have secure tenure to land, only those interventions that fit the customary land allocation procedures can be appropriate. Thus where rotational grazing schemes have failed due to communal grazing. fodder banks may be appropriate because they can be given the same regard as arable crop fields.

Availability of labour will also affect the choice of adoptable techniques. For instance, despite the dominant economic role of cattle in agro-pastoralism, where cropping is aimed at meeting family subsistence needs, cropping still has first call on any spare labour, and forage production techniques must depend on minimal labour inputs.

Hence the concentration on developing techniques whereby the cattle could prepare the seed beds and control the weed grasses by controlled grazing and thus obviate the need for additional labour or implements.

The high capital value of herds of cattle makes it possible, in the case of agro-pastoralists, to consider investments that would be beyond the reach of most small scale farmers. However, the willingness to invest is constrained by the attractiveness of investment in more stock and a general aversion to risk that is more difficult to overcome when a consensus is required from numerous people who may own different animals in the herd management unit. The fodder banks are relatively expensive, but the major investment in fencing does not conflict with the interest of any particular member of the household.

The effect of the three impositions discussed immediately above on the conduct of the FSR programme can be considered together because their main effects were the same and they compounded the problem. They collectively imposed the need for large samples and at the same time raised the logistical costs. Often a four-wheel-drive vehicle was needed to travel between participants and only a few could be visited in one day. This also created difficulties in data handling at the field level. Initially the team relied entirely on notebooks and pocket calculators. With the need for large numbers of herds, spread over vast distances, it was impossible for the scientists concerned to provide the level of supervision they would have wished. Supervision problems were compounded by delays in data analysis which was hampered by having to code and enter data at ILCA Head Quarters in Addis Ababa, Ethiopia, without access to the original books in Kaduna, Nigeria. No FSR team should now contemplate embarking on such a programme without adequate micro computer facilities. ILCA and NAPRI are cooperating in the provision of micro computer systems so that the NAPRI team gets the full benefit of ILCA's experience.

Extension Capability

Because of the long time frame before the impact of cattle extension

advice becomes apparent in increased animal productivity, livestock extension workers often have difficulty achieving an effective relationship with cattle owners. Disease control measures are a notable exception to that rule. Inadequate extension infrastructure, such as a shortage of transportation, is common. As a result of such problems the motivation of extension staff is generally rather low. This means that the interventions they are most likely to pursue will be those that achieve visible results without imposing too much additional stress on their facilities. The above supports the contention that extension workers should participate actively in FSR. The implications of such participation must be fully detailed and agreed to by the departments concerned.

For most of the life of the programme, its Kaduna offices were provided by the National Livestock Project Unit. Close links were also maintained with the state extension services. Most of the research was done at Kurmin Biri on a government-operated grazing reserve where there is constant interaction between extension and ILCA staff. The state has also allocated staff to work with ILCA each year and ILCA has mounted several workshops for extension staff. Consequently, the extension staff are actively extending ILCA's packages and assisting with monitoring the progress of fodder banks in their adoption and utilisation.

IMPOSITIONS OF THE RESEARCH SYSTEM

The following impositions have been selected both because they are important and because they interact with the impositions of the production systems discussed above.

Budget Limitations and Time Horizons

The difficulty of making budgetary adjustments to ongoing programmes is often underestimated. This means that future planning should not depend on expectations that are very much out of line with current practice in the sponsoring institution. Overly optimistic future

planning can lead to misallocation of resources such as over staffing associated with operating in expectation of increased funding. It can also foster competitive adversary situations where there should be collegiate interaction. The relative costs of working in different countries vary greatly, and this should be taken into account in determining research goals and methods for each particular FSR proposition. ILCA was fortunate that the Federal Government of Nigeria alleviated the above problems with financial and practical support of the programme.

The time taken first to develop an adoptable package, to encourage sufficient farmers to actually adopt it, and then to allow for the effects to be manifested in the production parameters such as calving intervals, was not reflected in the plans for the programme, nor was it provided for in the reporting procedures. With the benefit of experience, it should be possible to establish systems for monitoring the progress of interventions under test in an FSR programme as they pass through the various phases by which interventions are developed and tested. Interim reports on long-term protocols should indicate the phase at which the reports are based. This would facilitate a better appreciation of the strength and reliability of the results. On the basis of the experience of the ILCA Subhumid Programme, it appears that five to seven years is an appropriate time frame for an FSR programme involving cattle breeding enterprises.

Materials and Equipment

It is improbable that any FSR team will ever obtain all the material and equipment it believes it can justify. Moreover, the availability of items such as land will be very site-specific. For instance, it may not be possible to obtain land for experiments and grazing for research animals in a very intensively cultivated area. The availability of items such as laboratory equipment and reagents varies from country to country and even within countries. There may also be institutional prerogatives as to what the FSR team can or cannot do. For instance, while it might be desirable to carry out minor veterinary treatments in

order to secure participant goodwill, this may or may not be permissible and may or may not have to be under the supervision of government veterinarians. If the necessary materials and equipment are not specifically provided for at the outset, it is extremely difficult to make provision for them later.

Despite the fact that one of the attractions for working in the Subhumid Zone was that it was known to be under-researched and without any major research station, ILCA still felt able to move directly to on-farm research and no provision was made for the research team to have any land or animals under its control. This led to unnecessary risks being taken at the farm level with concepts derived from research stations in different environments. The need for some on-station research facilities in the case study areas was soon recognised. Fortunately, the Kaduna State Government, the Federal Livestock Department and the National Livestock Project Unit cooperated with ILCA to the extent that the programme now has approximately 30ha for experimental plots and 50 cattle for grazing trials. Without this assistance, the credibility of the whole programme would have been prejudiced. This experience reiterates the need for all major material and equipment needs to be very carefully assessed before any FSR programme is begun.

Team Composition

It is a common failing in planning new ventures to assume that it will be possible to recruit all the necessary staff of the right calibre. The ideal systems scientist must be interested in people and leadership, accustomed to hardship and travel, ambitious but team-minded and keen on interaction with other scientists, practical and good at improvisation. There is no such paragon. Moreover, it is frequently only possible to post young staff into remote areas that do not have such things as adequate schooling and job opportunities for wives. However, the recent training, ambition and vigour of youth can be assets. The fact that there is a direct human element to their work is a powerful incentive to the young scientist. This can lead to some

extraordinarily good work provided that the research programme includes individual research protocols that are within the capability and time frame of the scientists who will from time to time be employed.

ILCA's experience with household economic surveys may be used as an example of the problems that arise from undertaking research tasks with inadequate staffing. The surveys were undertaken with the objective of determining the income, expenditure and time budgets of pastoral and arable farming households. They were carried out with recognised procedures with twice weekly visits by enumerators, who sought every detail of the activities of complete households. Because of numerous factors such as a lack of appreciation of the amount of instruction and supervision required, the scientists were involved in too much other work to devote adequate time to the surveys. The data processing systems were also not adequate for handling such vast amounts of data. In consequence, the end result may prove to be questionable and is certainly too late to influence the design of the interventions. Later experience with case studies of a few households proved to be much more appropriate to the experience and time availability of the team member concerned.

Government Policy

The intended product of FSR is the development of "farmer-ready" interventions that can be promoted by the national extension and development agencies. If the interventions are not consistent with government policy, the interventions will not be extended whatever their technical merit. Government policy must, therefore, be incorporated as part of the environment of the farming system under study. This may include several tiers of government. In Nigeria it includes Federal, State and local governments.

The process of legitimizing FSR (Butler, 1984) was done very carefully, so this has presented no difficulty. For example, the delay of two years caused by the negotiation of the ILCA/Nigeria agreement has proven to be a very worthwhile investment. From the outset of the

programme close contact has been maintained with the senior Nigerian livestock policy makers. This was formalised by the appointment, by the Director of the Federal Livestock Department, of a Technical Advisory Committee under the Chairmanship of the Director of the National Animal Production Research Institute and the inclusion of a senior Nigerian in the team (at equivalent to Deputy Team Leader level) with strong experience in the Kaduna State Ministry of Agriculture and Forest Resources.

On-Station Research Support

The amount, quality and accessibility of relevant on-station research from the parent institution and other national and international research institutions should be taken into account because it will affect the amount and nature of the component research that will have to be carried out by the FSR team. This will not only affect the allocation of resources; it will also affect the scheduling of research items. If there is an absolute lack of proven technology for the particular environment, there will be a heavy initial commitment to component research. If, on the other hand, the basic ingredients for a testable package already exist, it may be preferable to introduce component research only once problems or opportunities for improvements have been identified through on-farm testing. Almost inevitably there will be a need for some on-station facilities under the control of the FSR team. FSR-related trials should normally involve only the minimum of changes in existing systems or else the results may not be fully relevant to the system under study. It is difficult, for instance, to imagine useful results on fodder bank grazing being obtained from herds maintained under research station conditions. The ILCA experimental herd is herded by Fulani alongside the cattle of the participant Fulani herd owners. As far as possible, only the treatment under study is altered (e.g., various fodder bank grazing periods).

However much regard research-station-based scientists have for FSR, it is not possible for them to undertake the continuing unpredictable series of small experiments that are necessary to resolve problems as

they arise in the course of FSR. The station-based scientists are constrained by their own work loads and by the procedures through which research protocols are selected and approved. FSR component research needs a high degree of flexibility so that problems that arise from on-farm trials can be handled in time for the following seasons on-farm trials. It is not feasable to run on-farm trials in only alternate years. In the case of ILCA's Subhumid Programme this is further complicated by the fact that the closest research station, NAPRI, is not situated in the Subhumid Zone.

National FSR teams, such as the recently created NAPRI Livestock Systems Research Team, will have less of a problem because the scientists will be able to incorporate some of the research they require into their own on-station commitments. The NAPRI team is also starting its research in the same ecological zone as the research centre.

SUMMARY AND CONCLUSION

The discussion of the benefits accruing to pastoralists adopting fodder banks supports ILCA's use of FSR and the choice of research topic. The ultimate test of FSR, which is farmer adoption (Behnke, 1984), is underway and, as noted above, also looks promising. That does not mean that there were no wrong steps taken. One of the major purposes of an international research organisation, such as ILCA, engaging in new research fields is to develop and test new research techniques and pass on its experiences; the exposition of pitfalls is as important as demonstrating the success.

There are many excellent texts on the identification of constraints in farming systems. This paper has, therefore, avoided repetition and concentrated on the implications of the constraints imposed on achievement of research goals by the impositions of the research and farming systems as they interact. The exposition of welfare goals and impositions due to the research system and the farming system are supported by examples drawn from the experience of the ILCA Subhumid

Programme.

The identification and resolution of the problems encountered in mounting an FSR project is a major benefit of pioneering research efforts. Despite such problems with the Subhumid Programme, ILCA's investment in FSR in the zone is showing signs of positive payoffs. Prior to the start of ILCA's Subhumid Programme there had been three decades of forage legume research in Nigeria, but there had been very little by way of transference to farmers' fields. The value of that original work is at once demonstrated by its employment in the FSR trials and at the same time clinched by its transfer to farmers' fields through the medium of FSR. It is hoped that the NAPRI Livestock Systems Research Team and other national FSR teams working with cattle will benefit from the experiences discussed above.

This paper suggests that, with more adequate analysis of how research and farming systems interact, FSR programmes and budgets can be devised so that the maximum advantage can be obtained from the commitment of resources made by both the research sponsors and the farmers.

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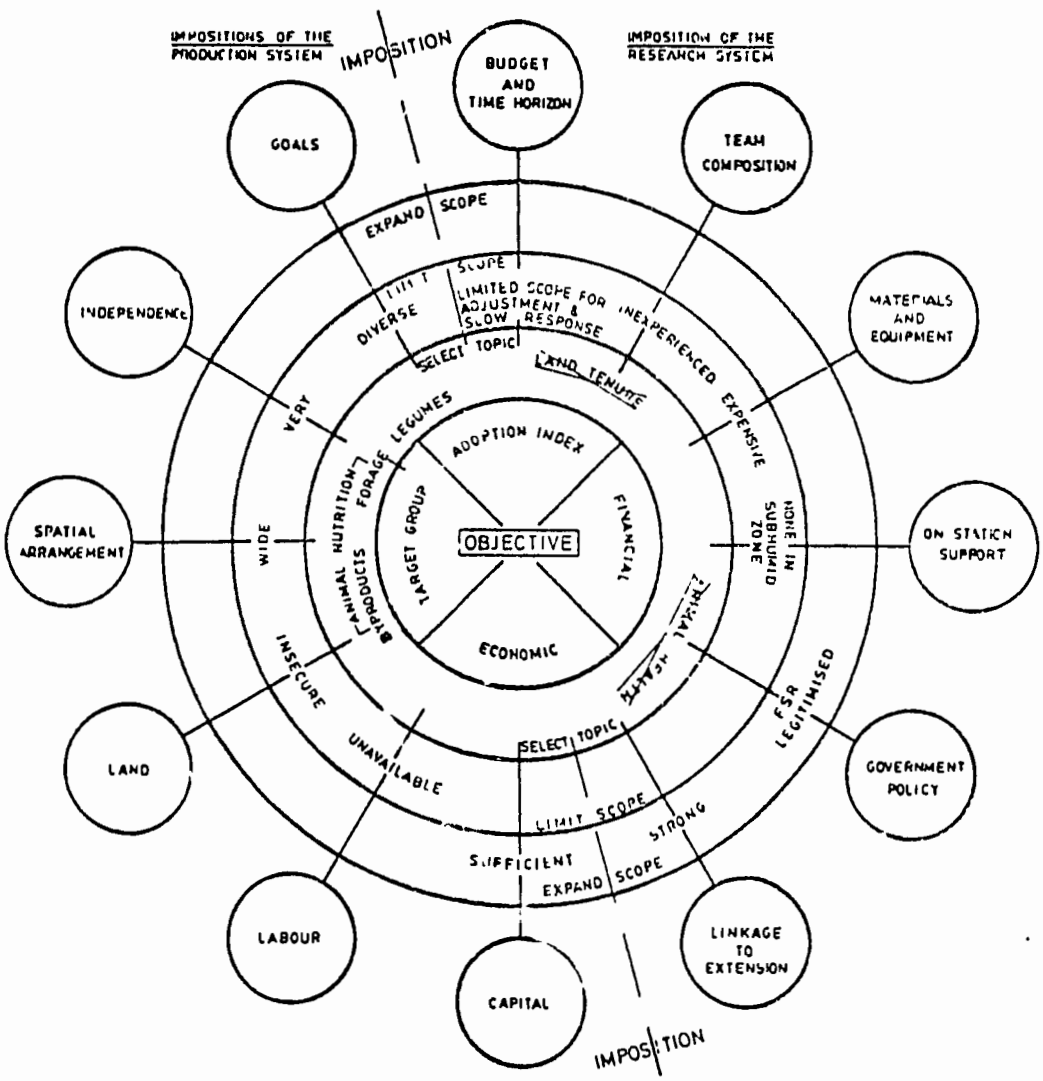
Figure 1. The impositions of the production and research systems as they interact.



Notes -

1. Above based on experience of ILCA subhumid programme emphasises contrast of livestock to farming systems
2. Constraints are limitations on production that comprise the impositions of one system on another as they interact
3. Propositions are rational suggestions for changes in behaviour, technology, management which will enhance the production relationship between one or more systems and minimise the constraints
4. Products are the results of the orchestrated interaction of systems in which constraints are minimized or overcome
5. Objective - FSR to produce farm-ready techniques to enhance farmer welfare
6. 1 2 3 4 from KRUPICKA etal 1984

DISCUSSION

Q. Given the experience of the Kaduna Program with ex-ante analysis, what role/value do you see it having in FSR?

A. Too much time can be spent in ex-ante appraisal. In the case of the Kaduna Program with the fencing of fodder banks, interaction with farmers was the major factor highlighting our error. All the ex-ante analysis has shown that fencing was taboo because they would threaten to transfer control permanently to the pastorialists who, however long they have been resident, are still regarded as temporary guests.

Comments:

I do not agree with the point that was made by the speaker that government policy should always determine what research is worth doing. I think the important thing is to bring the government or national institutions into the picture while developing technology. It is possible to come out with a research intervention which can lead the government to change its policy. Government policy is not always right.

As far as the Kaduna Project is concerned, government policy was taken into consideration right from the beginning of our technology development. The results of the research were then relayed back to the government authorities and the feedback from the government flowed back into the research cycle. Thus, it was a continuous cycle. Government policy was taken into account in determining the target producers and research priorities. The research that was done not only was disseminated through extension channels, but used in training and to provide information and advice for government authorities to develop policy goals.

MINERAL RESEARCH TECHNIQUES FOR RUMINANTS

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INTRODUCTION

Mineral deficiencies or imbalances in soils and forages have long been held responsible for low production and reproduction problems among grazing tropical cattle. Cattle grazing forages in severe P, Co or Cu-deficient areas are even more limited by lack of these elements than either that of energy or protein. Research from tropical regions has shown mineral supplementation to increase calving percentages by 20 to more than 100%, to increase growth rates from 10 to 25% and to reduce mortality significantly (McDowell and Conrad, 1977).

At least 15 mineral elements are nutritionally essential for ruminants. There are seven macronutrient minerals - Ca, P, K, Na, Cl, Mg and S and eight trace elements or microelements - Fe, I, Zn, Cu, Mn, Co, Mo and Se. In specific regions, toxic concentrations of Cu, F, Mn, Mo or Se limit grazing livestock production. Additional toxic elements (arsenic, lead, cadmium, mercury and aluminum) for ruminants as well as the possible significance of newly discovered essential elements (chromium, vanadium, nickel, tin, silicon and arsenic) have been reviewed (Underwood, 1981). Practical significance of the "newer" trace elements for ruminants has not been found, with evidence for essentiality based almost exclusively on growth effects of animals receiving highly purified diets. My remarks concerning mineral deficiencies and toxicities will be directed to grazing livestock. The discussion will emphasize incidence and methods of diagnosis including radioisotopes for herbivore mineral deficiencies and excesses.

Factors Influencing Mineral Requirements

Many factors affect mineral requirements, including nature and level of production, age, level and chemical form of elements, interrrelationship with other nutrients, mineral intake, breed and livestock adaptation. Improved management practices that lead to improved milk production and growth rates for livestock will necessitate more attention to mineral nutrition. Mineral deficiencies, perhaps only marginal until this time, are likely to become important, and previously unsuspected nutritional deficiency signs may occur as production levels increase (Long et al., 1972).

Specific mineral requirements are difficult to pinpoint since exact needs depend on chemical form and numerous mineral interrelationships. The chemical form of mineral elements varies greatly in amount of dietary mineral supplied and in biological availability (Ammerman and Miller, 1972). As an example, elemental Se is largely unavailable for chicks but is quite effective in protecting against Se deficiency in sheep and cattle (Underwood, 1981).

Adequate intake of forages by grazing ruminants is essential in meeting mineral requirements. Factors which greatly reduce forage intake, such as low protein content (<7.0%) and increased degree of lignification, likewise reduce the total minerals consumed.

Since tropical forages contain less minerals during the dry season, it is logical to assume that cattle would most likely suffer mineral inadequacies during this time. On the contrary, numerous reports, including those from Kenya (Hudson, 1944), Brazil (Correa, 1957) and Southern Africa (Van Niekerk, 1974), noted specific mineral deficiencies more prevalent during the wet season. Grazing cattle were more prone to develop Co or P deficiencies, and the clinical signs were severest after the rains when pasture were green and plentiful. From Southern Africa, Van Niekerk (1978) noted that the beneficial effect of supplemental P was primarily during the wet season, although the P

content in the grass was at its highest. Increased incidence of mineral deficiencies during the wet season is less related to forage mineral concentration than to the greatly increased requirements for these elements by the grazing animal. During the wet season, livestock gain weight rapidly since energy and protein supplies are adequate and thus the mineral requirements are high, while during the dry season inadequate protein and energy result in animals losing weight which lowers mineral requirements.

Sources of Minerals to Grazing Livestock

Grazing livestock from tropical countries often do not receive mineral supplementation except for common salt and must depend almost exclusively upon forages for their requirements. Only rarely, however, can tropical forages completely satisfy all mineral requirements. Table 1 summarizes the mineral concentrations of 2615 Latin American forages (McDowell et al., 1977). Borderline or deficient levels of certain elements were noted for many entries: Co, 43%; Cu, 47%; Mg, 35%; P, 73%; Na, 60%; and Zn, 75%.

Water is not normally a major source of minerals. Nevertheless, although highly variable, all mineral elements essential as dietary nutrients occur to some extent in water. Animals sometimes consume appreciable amounts of soil but this is also highly variable. High soil ingestion is favored by soils with a weak structure and poor drainage, high stocking rates and high earthworm populations during the winter months when pasture growth is poor. From New Zealand, annual ingestion of soil reached 75 kg for sheep and 600 kg for dairy animals (Healy, 1978). Soil ingestion, direct or due to pasture contamination, can result in higher intakes of Co and I since soils contain appreciably higher concentrations than plants, but the animal may likewise consume toxic elements (Egan, 1975).

Factors Affecting the Mineral Content of Plants

Concentrations of mineral elements in forage are dependent upon the

interaction of a number of factors, including soil, plant species, stage of maturity, yield, pasture management and climate. Most naturally occurring mineral deficiencies in herbivores are associated with specific regions and are directly related to soil characteristics. Young and alkaline geological formulations are more abundant in most trace elements than the older, more acid, coarse, sandy formations (Hartmans, 1970). Poor drainage conditions often increase extractable trace elements (e.g., Mn and Co), thereby resulting in a corresponding increase in plant uptake (Mitchell et al., 1957). As soil pH increases, availability and uptake of Fe, Mn, Zn, Cu and Co decreases whereas Mo and Se concentrations increase (Pfander, 1971).

Large variations in mineral content of different plant species growing on the same soil have been reported. As plants mature, mineral contents decline due to a natural dilution process and translocation of nutrients to the root system (Tergas and Blue, 1971). Increasing crop yields remove minerals from the soil at a faster rate so deficiencies are frequently found on the most progressive farms. Overuse of N and K fertilizers increase the incidence of grass tetany, with K also dramatically reducing forage Na content (Underwood, 1981). Overliming can accentuate a Se or Mo toxicity in livestock by increasing plant concentrations of these elements and at the same time favor Co and Mn deficiencies due to lowered plant uptake.

Mineral Deficiencies and Toxicities in Tropical Regions

Mineral deficiencies and imbalances for herbivores are reported from almost all tropical regions of the world. Table 2 lists reports of mineral deficiencies or toxicities in Africa, Latin America and Asian tropical countries. These reports include both confirmed and highly suspected geographical areas of mineral deficiencies and toxicities in cattle. Listing countries constitutes a very generalized approach, with important geographical omissions inevitable but it does indicate the scope of the problem. The extent of affected areas is not generally appreciated and it is inevitable that reports of mineral inadequacies will greatly increase as more tropical countries undertake

mineral research and thereby improve their methods of detection.

The mineral most likely deficient for grazing cattle is P, follwed by Cu and Co. Deficiencies of Na and I are equally widespread, as are lack of Co and Cu. However, under most circumstances, deficiencies of Co and Cu generally are more detrimental to ruminant production than either Na or I. Toxicity of both Se and F are widespread throughout the tropical countries of the world.

Diagnosis of Mineral Deficiencies and Imbalances

Mineral nutrition disorders range from acute mineral deficiency or toxicity disease, charcterized by well-marked clinical signs and pathological changes, to mild and transient conditions difficult to diagnose and expressed as a vague unthriftiness or unsatisfactory growth and production (Underwood, 1981). The latter assume great importance because they occur over large areas and affect a high number of animals, in addition to the fact that they can be confused with energy and/or protein dificiencies or parasitism (Underwood, 1981).

Clinical signs of mineral deficiencies, pathological and biochemical examinations - along with soil, water, plant and animal tissue and fluid mineral analyses - have all been used with varying degrees of success to establish mineral deficiencies and excesses. The most reliable method of confirming mineral deficiencies is reponse derived from specific mineral supplementation. However, such studies are costly in time and resources if conducted with adequate control and assessment. The majority of mineral imbalances, particularly borderline conditions, do not result in pathological observations of clinical sign specific to a single mineral. Therefore, in order to determine mineral insufficiencies, chemical analyses and biological assays are often required.

Analyses to determine the available forms of soil minerals can sometimes provide clues to livestock mineral deficiencies but more often they are unreliable and difficult to interpret. Data from Brazil

(Conrad et al., 1980), Bolivia (McDowell et al, 1982) and Florida, U.S.A. (Kiatoko et al., 1982) have indicated that mineral correlations among soil, plant and animal tissue concentrations were highly variable among locations and often low or nonexistent. Typical forage-soil correlations reported in Brazil were Fe ($r = 0.12$), Mn ($r = -.12$) and Zn ($r = 0.30$) (Conrad et al., 1980). Disadvantages of forage element analyses to assess mineral adequacy for grazing livestock include: 1) uncertainty of samples representing what livestock consume; 2) difficulty of estimating forage intake; 3) variation in the availability of forage elements; and 4) the possibility of soil contaminated forage samples. Nevertheless, forage mineral analyses are preferable to soil analyses, while appropriate animal tissue and fluid analyses most accurately portray the contribution of the total dietary environment (forage, soil, water, etc.) in meeting livestock mineral requirements.

Animal tissue and fluid levels of minerals, in addition to concentrations of particular enzymes, metabolites or organic compounds with which the mineral in question is functionally associated, are important indicators of mineral status. Whole blood or blood serum or plasma is widely employed for studies in mineral nutrition. Values significantly and consistently above or below "normal" concentrations or ranges provide suggestive but not conclusive evidence of a dietary excess or deficiency of particular minerals. Precautions must be taken in interpreting blood mineral data collected or prepared in less than optimum conditions. Factors responsible for elevation of serum or plasma minerals include stress, exercise, hemolysis, temperature and serum separation time (Fick et al., 1979). These factors have often been difficult to control in studies from Latin America (McDowell et al., 1983) and Africa (Mtimuni, 1982) and have resulted in high serum P concentrations compared to extremely low levels of forage P. Due to the limitations of serum P as an indicator of status, bone P concentrations would be the analysis of choice. From Africa, a 21% increase in cow productivity resulted from P supplementation although normal plasma P concentrations were in evidence (Ward, 1968).

Since mineral analyses are complicated and expensive, it is important to select and analyze the minimum number of plant and animal tissues which are more indicative of the mineral status. Table 3 illustrates analyses of considerable value in assessing specific mineral deficiencies and toxicities.

A Mapping Technique for Determining Mineral Deficiencies and Toxicities

Mineral deficiencies or toxicities in grazing livestock can be predicted by use of a systematic mapping survey technique or regional reconnaissance. Analyzed Se and Co levels of U.S. forages have been related to Se and Co responsive diseases (Kubota, 1968). Similar mapping techniques based on forage analysis have been undertaken for Ca and P in Brazil (Gavillon and Quadrso, 1970) and Se in Venezuela (Jaffe et al., 1969). Egan (1975) reported that the sampling and analysis of stream bed sediments have revealed areas of hitherto unsuspected Mo-induced Cu deficiency in sheep and cattle, Mn deficiency in cattle and Co deficiency in sheep. Cobalt and/or Cu deficiencies of grazing ruminants have also been established in specific Brazilian regions as a result of low liver concentrations of these elements (Tokarnia and Dobereiner, 1973). Deficiencies of P, likewise, were established in Venezuela and in Panama on the basis of low serum P levels.

From Uganda, the mineral status of dairy farms was established from analyses of local pastures (Long et al., 1972). Boyazoglu (1973) analyzed liver samples for trace elements and identified mineral deficiencies in ten regions of South Africa and its adjoining territories. Liver Cu concentrations from Sudan (Tartour, 1975) and Southern Africa (Van Niekerk, 1978) have been used to detect areas of Cu deficiencies.

Since 1974, the University of Florida, with support from the Agency for International Development, has been engaged in cooperative mineral research with institutions in Latin America, Africa and Southeast Asia. The purpose of this research is to locate mineral deficiencies or excesses for grazing livestock by use of a systematic mapping technique

which analyzes plant and animal tissues and by observing the biological response from mineral supplements. A systematic mapping technique using forage and animal tissue analyses has been carried out in large areas of Colombia (Laredo, 1981), Costa Rica (Vargas et al., 1980) and Venezuela (Velasquez, 1979).

Undergraduate and graduate student programs can be used to effectively carry out mineral research programs. As an example, 29 recent theses have been completed in Costa Rica by students in the Department of Animal Science at the University of Costa Rica. These students would be responsible for samples collected from different regions of the country during a specific season. They would be responsible for the analysis, literature review, statistical evaluation and writing up the thesis. For graduate students at the University of Florida, the students would do their course work at Florida and then return to their native country for the purpose of organizing research and collecting data. Research would be carried out in areas where ruminant livestock production was low. A typical experimental design would be to locate two to three regions within a particular country where ruminant livestock production is low. Within these regions two to four farms would be selected. Within these farms often two classes of animals would be tested, such as comparing pregnant lactating animals to growing animals. From these animals samples of liver, blood and sometimes feces and bone would taken. In addition, forage and soil samples would be taken from these farms. Often samples would be collected twice during the year from the same farm. Sample collection periods would represent the end of both the wet and dry seasons. On the basis of this information, it would be possible to devise the most suitable mineral supplement for a specific region.

In some instances, animal tissues would be collected directly on the farm (e.g., liver and/or bone biopsies). For other locations, samples would be collected at slaughter houses. Upon collecting the samples at slaughter houses, visits would then be made to the farms where the animals originated for the collection of forage and soil samples.

Some researchers feel that meaningful research can only be carried out on large farms due to the needed numbers in order to find significant differences. This is not always true and there are examples where successful research has been carried out on small farming systems. As an example in 1978, forage, blood and liver samples were taken from 12 ranches during both the wet and dry seasons. The majority of these farms had only 10 to 15 animals, however, liver biopsies were successfully taken from these farms without any difficulty. Ideally it is best to carry out an experiment all on one farm, however, experiments can be designed where different farms will serve as different treatments. This is assuming that all of the management characteristics are basically similar, therefore, it would be possible to compare production rates with some farms receiving various minerals while others serve as controls.

In determining mineral deficiencies or excesses, element analyses are indispensable. Neutron activation is a desirable method of analysis for a large number of mineral analyses. The method is non-destructive, results in extremely low detection limits and allows a considerably high number of simultaneously detectable elements. Radioactive and stable isotopes have proven to be valuable tools in analystical procedures and in studies on mineral metabolism. Isotopes can be used to follow mineral elements in soils and plants and to test their stability during processing for analysis. An isotope in a fertilizer can be used as a "label" or "tracer" to determine how much of a fertilizer nutrient applied to a crop is actually used and how much is left as a potential pollutant (IAEA, 1984).

The extent of absorption, retention and excretion of an element are dependent upon the status of the animal. Thus, a deficiency of a mineral can be established on the basis of absorption retention and excretion of an isotope of a particular element. Kirchgessner and Schwarz (1976) discussed three models for the use of radioisotopes in the diagnosis of mineral element deficiency: 1) determination of intestinal absorption of an orally administered radioisotope by measuring the activity of blood; 2) determination of the retention of a

parenterally administered dose of blood or plasma; and 3) determination of the endogeneous fecal excretion of a parenterally administered dose.

The employment of radioisotopes makes it possible to demonstrate the dynamics of mineral elements and to arrive at quantitative assessments about pathways of homeostatic regulation. For rats, Kirchgessner and Schwarz (1976) reported higher in vitro absorption for deficiency versus adequacy in Ng for Cu (28.5 vs 8.9), Zn (68.1 vs 17.0) and Fe (17.9 vs 6.7), respectively. In vitro techniques involving addition of radioisotopes to collected blood samples have been used to evaluate the mineral status of a number of minerals (i.e., ^{75}Se and ^{65}Zn). As an example, the erythrocyte uptake of ^{75}Se has proved to be a promising technique to evaluate Se status. The erythrocytes of a Se deficient animal will have a much higher uptake of ^{75}Se than animals with a normal Se status. This procedure is of value since blood samples could be collected even under nomadic conditions since animals are at times assembled at stations for vaccination or other reasons.

Methods of Providing Minerals to Grazing Livestock

Indirect methods of providing minerals to grazing cattle include use of mineral-containing fertilizers, the alteration of soil pH and the encouragement of growth of specific pasture species. Underwood (1981) reports that the indirect approach, as a means of controlling mineral deficiencies, is not without its problems arising from the greater complexity of soil-plant-mineral interrelations and difficulties related to erratic climate and cost.

Where economic and climatic considerations are favorable, fertilizer treatment of the soils is an effective means of improving both the yields and mineral composition of herbage. Recent Australian research (1981) has shown that not only does superphosphate fertilizer increase herbage P but results in improved palatability and digestibility of the forage. Increased mineral content of forages through fertilization has an additional advantage of assuring a more uniform mineral consumption as all animals would be consuming higher quantities of minerals in the

forage. The major problem with free-choice mineral supplements is that not all animals in a herd will consume adequate quantities. Unless there are definite forage yield increases which can be utilized effectively by grazing herbivores, use of mineral-containing fertilizers is economically prohibitive. Direct administration of minerals to cattle in water, mineral licks, mixtures and drenches, rumen preparations (i.e., Co pellets, copper oxide needles and glass bullets containing various trace elements) and injections are generally the most economical methods of supplementation. Benefits and disadvantages of mineral supplementation methods are discussed by Underwood (1981).

Selecting a Free-Choice Mineral Supplement

Even though grazing livestock have been found not to balance their mineral needs perfectly when consuming a free-choice mixture, there is no other practical way of supplying mineral needs under grazing conditions. As a low cost insurance to provide adequate mineral nutrition, "complete" mineral supplements should be available free-choice to grazing livestock (Cunha et al., 1964). A "complete" mineral mixture usually includes salt, a low fluoride P source, Ca, Co, Cu, I, Mn and Zn. Selenium, Mg, K, S, Fe or additional elements can also be incorporated into a mineral supplement or can be included at a later date as new information suggests a need. In the case of Mg, an oral supplement would only be of value during the seasonal occurrences of grass tetany (Allcroft, 1961). Calcium, Cu or Se, when in excess, can be more deterimental to ruminant production than any benefit derived by providing a mineral supplement. In regions where high forage Mo predominates, three to five times the Cu content in mineral mixtures is needed to counteract Mo toxicity (Cunha et al, 1964). Thus, the exact level of Cu to use in counteracting Mo toxicity is a complex problem and should be worked out for each area. Table 4 lists the characteristics of a "good" mineral supplement.

In relation to feeding minerals, a number of "authorities" feel there is no justification for the use of "shotgun" (complete) free-choice

mineral mixtures which are designed to cover a wide range of environments and feeding regimens and which contain a margin of safety as an insurance against deficiency. The "authorities" feel that "shotgun" mixtures are economically wasteful and can also be harmful. The present author is in disagreement with this viewpoint in relation to "shotgun" mixtures for cattle. There is little danger of toxicity or excessive cost in relation to the high probability of increased production rates for cattle from administering a complete ("shotgun") free-choice mineral mixture following the guidelines in Table 4. Copper and Se added at recommended levels would be the minerals of most concern for toxicity. However, cattle, contrary to sheep, are much less sensitive to Cu toxicity and inorganic forms of Se (i.e., sodium selenite) are not well utilized by livestock when administered in excess of the requirements. In conclusion, it is best to formulate free-choice mixtures on the basis of analyses or other available data. However, when no information on mineral status is known for a given region, a free-choice complete ("shotgun") mineral supplement is definitely warranted.

Mineral Supplement Evaluation

Problems concerned with mineral supplementation programs in diverse tropical regions have been summarized (McDowell and Conrad, 1977; McDowell et al., 1983) and include: 1) insufficient chemical analyses and biological data to determine which minerals are required and in what quantitites; 2) lack of mineral consumption data needed for formulating supplements; 3) inaccurate and/or unreliable information on mineral ingredient labels; 4) supplements that contain inadequate amounts or imbalances; 5) standardized mineral mixtures that are inflexible for diverse ecological regions (i.e., mineral mixtures diluted 10:1 and 100:1 with additional salt); and 7) difficulties involved with transportation, storage and cost of mineral supplements.

Some of the information necessary to evaluate mineral supplements can be found printed on the bag or a tag securely attached to the bag or, in the case of bulk shipments, attached to the invoice or other papers

involved in the sale. This information is sometimes incorrect and is expressed in different ways, making it difficult for the layman to determine what is being purchased and if it is adequate for the purpose intended.

The concentration of elements in the mineral mixture, in most cases, is suppplied by the manufaturer on the mineral tag. Making a judgment from such a tag assumes, of course, that the quality control of the supplement has been such that the mixture actually contains the amount stated on the tag. Unfortunately, this has not proven to be the case in many instances. Analyses of mineral mixtures collected throughout Latin America have often shown little relationship between the amount of elements listed on the tag and those actually found in the supplement.

Responsible firms that manufacture and sell high quality mineral supplements provide a great service to individual farmers. However, there are companies that are responsible for exaggerated claims of advertising and some that produce inferior products that are of little value or, worse, those likely to be of detriment to animal production. Table 5 provides an example of an inferior mineral mixture available in Latin America. This particular mineral supplement is recommended for cattle, sheep, pigs and chickens. It is impossible to meet requirements of both ruminants and monogastric animals with the same mixture. This imbalanced mineral mixture, which is extremely high in Ca (29.4%) and low in P (1.8%), would likely be more detrimental to grazing cattle than having no access to supplemental minerals.

Investigations from Ecuador have illustrated the problem of unreliability of some companies that sell mineral supplements (Fausto Rivera, personal communication). Fifty products claiming to contain minerals were analyzed in relation to stated guarantees. Approximately 10% were reliable, with the majority having inaccurate information on mineral ingredient labels and others providing inadequate amounts or mineral imbalances. An extreme known fraudulent practice of one particular supplier was to buy a relatively good product from the

marketplace, mix it with 20-30% soil and then resell the resulting mixture under a new brand name.

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TABLE 1. MINERAL BREAKDOWN AND CONCENTRATIONS OF 2615 LATIN AMERICAN FORAGES (DRY BASIS)[a]

Element	Percentage of forages with entries[b]	Number of entries	Requirement[c]			
Calcium	42.9	1123	0.18-0.60%	Concentracions, %	0-0.30	over 0.30
				% of total	31.1	68.9
Cobalt	5.4	140	0.05-0.10 ppm	Concentracions, ppm	0-0.10	over 0.10
				% of total	43.1	56.9
Copper	9.0	236	4-10 ppm	Concentracions, ppm	0-10	over 10
				% of total	46.6	53.4
Iron	9.8	256	10-100 ppm	Concentracions, ppm	0-100	over 100
				% of total	24.1	75.9
Magnesium	11.1	290	0.04-0.18 ppm	Concentracions, %	0-0.20	over 0.20
				% of total	35.2	64.8
Manganese	11.2	293	20-40 ppm	Concentracions, ppm	0-40	over 40
				% of total	21.0	79.0
Molybdenum	5.1	133	0.01 ppm or less	Concentracions, ppm	0-3	over 3.0
				% of total	86.4	13.6
Phosphorus	43.2	1129	0.18-0.43%	Concentracions, %	0-0.30	over 0.30
				% of total	72.8	27.2
Potassium	7.6	198	0.60-0.80%	Concentracions, %	0-0.80	over 0.80
				% of total	15.1	84.9
Sodium	5.6	146	0.10%	Concentracions, %	0-0.10	over 0.10
				% of total	59.5	40.5
Zinc	6.9	177	10-50 ppm	Concentracions, ppm	0.50	over 50
				% of total	74.6	22.4

[a]Latin American Tables of Feed Composition, McDowell et al. 1978.

[b]Less than 1% of the other minerals were included.

[c]Summarized by McDowell et al. 1978.

TABLE 2. GEOGRAPHICAL LOCATIONS OF MINERAL DEFICIENCIES OR TOXICITIES OF RUMINANTS IN TROPICAL COUNTRIES OF LATIN AMERICAN, AFRICA AND ASIA[a]

Required Elements	
Calcium	Argentina, Bolivia, Brazil, Colombia, Costa Rica, El Salvador, Guatemala, Guyana, India, Malawi, Mexico, Panama, Peru, Philippines, Senegal, Suriname, Uganda, Venezuela, Zaire.
Magnesium	Argentina, Brazil, Chile, Colombia, Costa Rica, Guatemala, Guyana, Haiti, Honduras, Jamaica, Kenya, Malawi, Nigeria, Peru, South Africa, Suriname, Trinidad, Uganda, Uruguay, Venezuela.
Phosphorus	Antigua, Argentina, Bolivia, Botswana, Brazil, Ceylon, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Egypt, El Salvador, Ghana, Guatemala, Guyana, Haiti, Honduras, India, Indonesia, Jamaica, Kenya, Malagasy Republic, Malawi, Malaysia, Mexico, Nicaragua, Nigeria, Panama, Paraguay, Peru, Philippines, Puerto Rico, Senegal, Somalia, South Africa, Suriname, Swaziland, Tanzania, Trinidad, Uganda, Uruguay, Venezuela, Zaire, Zimbabwe.
Potassium	Brazil, Haiti, Nigeria, Panama, Swaziland, Uganda, Venezuela.
Sodium	Bolivia, Brazil, Chad, Colombia, Dominican Republic, Guatemala, Kenya, Malawi, New Guinea, Nigeria, Panama, Philippines, Senegal, Somalia, South Africa, Suriname, Swaziland, Thailand, Uganda, Uruguay, Venezuela.
Sulfur	Brazil, Colombia, Ecuador, Uganda.
Cobalt	Argentina, Brazil, Colombia, Costa Rica, Cuba, Egypt, El Salvador, Guyana, Haiti, India, Indonesia, Katanga, Kenya, Malaysia, Mexico, Nicaragua, N. Africa, Peru, South Africa, Suriname, Uganda, Uruguay, Zaire.
Copper (or molybdenum toxicity)	Argentina, Bolivia, Brazil, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Ethiopia, Guatemala, Guyana, Haiti, Honduras, India, Indonesia, Kenya, Malaysia, Malawi, Mexico, Panama, Peru, Philippines, Senegal. South Africa, Sudan, Suriname, Swaziland, Tanzania, Trinidad, Uruguay, Venezuela, Zaire, Zimbabwe.

Table 2. (continued)

Iodine	Worldwide
Iron	Brazil, Costa Rica, India, Panama.
Manganese	Argentina, Brazil, Burma, Costa Rica, Panama, South Africa, Uganda.
Selenium	Bahamas, Bolivia, Brazil, Colombia, Costa Rica, Dominican Republic, Ecuador, Guyana, Honduras, Indonesia, Malawi, Mexico, Paraguay, Peru, South Africa, Swaziland, Thailand, Uganda, Uruguay, Venezuela.
Zinc	Argentina, Bolivia, Brazil, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, India, Indonesia, Kenya, Malawi, Mexico, Panama, Peru, Philippines, Puerto Rico, South Africa, Sudan, Swaziland, Uganda, Uruguay, Venezuela.
Toxic Elements	
Fluorine	Algeria, Argentina, Ecuador, Guyana, India, Mexico, Morocco, Saudi Arabia, South Africa, Tanzania, Tunisia.
Manganese	Brazil, Costa Rica, Indonesia, Peru, Suriname.
Selenium	Argentina, Brazil, Central African Republic, Chad, Chile, Colombia, Ecuador, Honduras, India, Iran, Kenya, Madagascar, Mexico, Nigeria, N. Africa, Peru, Puerto Rico, South Africa, Sudan, Upper Volta, Venezuela.

[a]McDowell et al. 1983.

TABLE 3. DIAGNOSIS OF SPECIFIC MINERAL DEFICIENCIES OR TOXICITIES IN CATTLE

Element	Animal requirement: Dairy cow[d]	Animal requirement: Beef cattle[e]	Tissue	Critical levels[a,b,c]
Deficiency				
Calcium	0.54%	0.18-1.04%	Bone (fat free)	24.5%
			Bone ash	37.6%
			Plasma	8 mg/100 ml
Magnesium	0.20%	0.04-0.10%	Serum	1-2 mg/100 ml
			Urine	2-10 mg/100 ml
Phosphorus	0.38%	0.18-0.70%	Bone (fat free)	11.5%
			Bone ash	17.6%
			Plasma	4.5 mg/100 ml
Potassium	0.80%	0.60-0.80%		
Sodium	0.18%	0.06%	Saliva	100-200 mg/100 ml
Sulfur	0.20%	0.10%		
Cobalt	0.10 ppm	0.05-0.10 ppm	Liver	0.05-0.07 ppm
Copper	10 ppm	4 ppm	Liver	25.75 ppm
			Serum	0.65 g/ml
Iodine	0.50 ppm		Milk	300 g/day
Iron	50 ppm	10 ppm	Hemoglobin	10 g/100 ml
			Transferrin	13-15% saturation
Manganese	40 ppm	1-10 ppm	Liver	6 ppm
Selenium	0.1 ppm	0.1 ppm	Liver	0.25 ppm
			Serum	0.03 g/ml
			Hair	0.25

Table 3. (continued)

Element	Animal requirement: Dairy cow[d]	Animal requirement: Beef cattle[e]	Tissue	Critical levels[a,b,c]
Toxicity				
Zinc	40 ppm	20-30 ppm	Serum	0.6-0.8 g/ml
Copper	80 ppm	115 ppm	Liver	700 ppm
Fluorine	30 ppm	40 ppm	Bone	4,500-5,500 ppm
Manganese	1000 ppm	150 ppm	Hair	70 ppm
Molybdenum	6 ppm	10 ppm	Liver	4 ppm
Selenium	5 ppm	5 ppm	Liver Hair	5-15 ppm 10 ppm

[a]References for critical levels are found in the following reviews: McDowell et al. 1983.

[b]Non-mineral assays for the following elements are sensitive diagnostic techniques: cobalt (vitamin B_{12}), iodine (free thyroxine), copper (ceruloplasmin) and selenium (glutathione peroxidase).

[c]Soil concentrations suggesting deficiencies are as follows: calcium (0.35 meq/100 g), potassium (0.15 meq/100 g), magnesium (0.07 meq/100 g), phosphorus (10 ppm), cobalt (0.1 ppm), copper (0.6 ppm), manganese (19 ppm) and zinc (2 ppm).

[d]Recommendations for lactating dairy cows (500 kg) giving 17-23 kg milk (NRC, 1978).

[e]Recommendations for growing, fattening steers and heifers (NRC, 1984).

TABLE 4. CHARACTERISTICS OF A "GOOD" FREE CHOICE CATTLE MINERAL SUPPLEMENT

An acceptable cattle mineral supplement should be as follows:

1. Final mixture containing a minimum of 6-8% total P. In area where forages are consistently lower than 0.20%, mineral supplements in the 8-10% P range are preferred.

2. Calcium-phosphorus ratio, not substantially over 2:1.

3. Provide a significant proportion (i.e., 50%) of the trace mineral requirements of Co, Cu, I, Mn and Zn. In known trace mineral deficient regions, 100% of specific trace minerals should be provided.

4. Composed of high quality mineral salts that provide the biologically available forms of each mineral element. Avoidance of and/or minimal inclusion of mineral salts containing toxic elements (i.e., phosphates containing high F concentrations).

5. Formulated to be sufficiently palatable to allow adequate consumption in relation to requirements.

6. Backed by a reputable manufacturer with quality control guarantees as to accuracy of mineral supplement label.

7. An acceptable particle size which will allow adequate mixing without smaller size particles settling out.

TABLE 5. AN EXAMPLE OF AN INFERIOR MINERAL MIXTURE AVAILABLE IN LATIN AMERICA[a,b]

Element mixture	Dietary allowance	Percentage in mineral mixture	Amount provided from mineral mix	Percentage of allowance for mineral
Sodium Chloride	0.50%	20.00	0.10%	20.0
Calcium	0.30%	29.44	0.147%	49.1
Phosphorus	0.25%	1.80	0.009%	3.6
Magnesium	2000 ppm	3.2	0.016%	8.0
Iron	100 ppm	0.88	44 ppm	44.0
Zinc	50 ppm	0.02	1 ppm	2.0
Cobalt	0.1 ppm	0.002	0.1 ppm	100
Iodine	0.80 ppm	0.001	0.05 ppm	6.25
Copper	10 ppm	0.001	0.75 ppm	7.5
Magnese	25 ppm	0.075	3.75 ppm	15.0
Selenium	0.1 ppm	0.0005	0.025 ppm	25.0

[a]Mineral mixture is recommended for cattle, sheep, pigs and chickens. It is assumed that mineral consumption will average approximately 0.5% of the total dietary intake. This is based on an estimated intake of 50 g of mineral mixture for cattle and 10 kg of total dry feed per head daily.

[b]Criticisms of mineral mixture are as follows: a) mixture extemely low in P and exceptionally high in Ca. The Ca:P ratios is 16.4:1; b) the supplement does not provide a significant proportion (i.e., 50%) of the trace mineral requirements of Cu, I, Mn and Zn; c) the majority of the Fe is from ferric oxide, an unavailable form of this element; d) since this diet contains 29.4% Ca and only 20% salt (NaCl), it is likely to be of low palatability.

DISCUSSION

Q. What is the minimum sample size for assessing the mineral status of animals on farms?

A. One can start with slaughterhouse samples and get some idea of variation in tissues. One can also use a questionnaire to assess the variability of farms and their management in a particular area. A statistician would probably answer this question by asking the question as to how much variation do you expect among animals. Obviously, it is hard for one to answer this question until one has done the analysis. There are always variations among animals. However, if they are in essence receiving the same diet with the same management, the variation is reduced. In practice, we take from 6-12 samples per class of animal for both the wet and dry seasons. Often we see, however, that differences are so great between regions or farms that two samples per class of animal could have been enough. In order to significantly detect differences, at least six samples are preferred. If management is the same among farms, then a design can be used which will include animals from a number of small farms to serve as one treatment. We can get into controversy with this type of design. Nevertheless, we can get good information on mineral status by using small farms. Sometimes I feel we get carried away as to whether there are significant differences. I feel it is much more important to determine how many samples are below or above critical concentrations which indicate mineral deficiencies or toxicities. I am more concerned in determining significant production parameter differences when comparing mineral supplementation treatments.

Q. You stated that there is a low correlation between the soil mineral content and forage mineral content. In Mali, one would run into trouble if you wanted to get samples from liver and bone.

What methodology can one use to identify mineral deficiencies?

A. If it is not possible to collect forage samples that represent what the animal is consuming or collect tissue samples, I would suggest mineral supplementation trials. Various treatments of minerals can be given to measure production response. For small farms where common grazing is practical, one approach is to provide minerals for ruminants on some farms where animals return at night. If it is impossible to nave separate pastures for individual treatments, then trace mineral applications can be made through mineral injections; (i.e. copper, zinc, selenium and iodine); or by cobalt or selenium bullets; or use of copper needles or rumen preparations of slow release glass preparations.

Q. In cases where getting samples from live farm animals for analysis of mineral deficiency is not possible, can not the researcher obtain samples from slaughtered animals from slaughterhouses?

A. Yes, animal tissue samples can be collected from either farms or slaughterhouses. The greatest precaution to exercise at either collection site is to obtain samples from animals in active production. As an example, a cow who has not produced a calf for several years (for whatever reason) generally has an adequate mineral status. Pregnant/lactating and growing animals are under production stress and will be the best indicators for the need of minerals. On the farm, samples from both classes of animals could be collected and compared with samples from slaughterhouse animals that have been growing. In slaughterhouses, it is good to collect only from animals where the farm of origin is known. In this way, the farm can be visited and questions asked about management and samples collected of forages and possibly of soils.

Q. You mentioned that hair loss is one symptom of zinc deficiency. There are definitely other nutritional and disease situations that also cause hair loss. For instance, minosine toxicity through the feeding of leucaena is reported to result in loss of hair. Is

there a possibility that supplementation of zinc of animals fed leucaena may minimize the chance of hair loss?

A. Hair loss in ruminants following leucaena feeding is the result of mimosine toxicity. I am, however, not certain if there is a link between this and zinc deficiency. a number of conditions will result in hair loss, including zinc deficiency, which will also result in skin lesions. To my knowledge, there is no relationship of mimosine toxicity to zinc deficiency.

Q. The necessity of taking forage samples to assess nutritional status of animals is costly and requires considerable time. With small farms, the task becomes almost impossible. What would you suggest as a step-by-step approach?

A. One could start on a regional basis with samples from bones and other tissues at the abattoir. Within a region, one could take blood samples on farms. If we are to use analysis to establish mineral deficiencies or toxicities, I feel it is imperative to evaluate dietary mineral concentrations There are many problems associated with tissue mineral analysis. As an example, plasma or serum phosphorous concentration can be increased by animal stress or exercise, water deprivation hemolysis, increased temperatures and separation time of plasma or serum from whole blood. Liver samples can be easily contaminated so that erroneous conclusions are drawn. It is more difficult to prepare tissues than forage samples for analysis and thus avoid error. Only laboratories with well trained technicians and equipment should be used. I feel a combination of both forage and animal tissue will give us our best indication of animal mineral status. If we cannot get forage samples or do not feel our sample collection for analysis procedures are adequate, we should rely on comparative mineral supplementation trials.

Q. Do principles of mineral nutrition apply equally to goats and sheep?

A. We know much less about the mineral requirements of goats than sheep. The National Research Council's publication on nutrient requirements of goats does not contain much information in relation to goats' mineral requirements. It is felt that goats suffer less loss from copper deficiency than sheep. I would expect less mineral deficiencies, particularly trace elements, for goats than sheep. The reason for this is that goats are browsers vs. grazers. Therefore, goats have a greater variety of diet including shrubs and tree leaves which are often higher in minerals than typical pastures.

Comments:

Various papers from this workshop as well as the ICARDA/IDRC workshop have mentioned the use of supplementation trials. We have concluded that energy, protein and mineral supplements are important. Likewise, we should consider if a vitamin supplementation is needed. For the grazing ruminant, the vitamin of concern is Vitamin A. When animals receive green forage they are receiving a good source of Vitamin A (carotene, vitamin percursor). However, when grazing more, there is a great danger of Vitamin A deficiency. It is reported that clinical signs (that is, watering eyes) from Vitamin A deficiency have been observed in both East and West Africa and that there was response to Vitamin A injections. Another consideration is that zinc deficiency can indirectly result in a Vitamin A deficiency. Zinc is required for the mobilization of Vitamin A from the liver. With a zinc deficiency there is low blood Vitamin A levels, even though liver Vitamin A is adequate. It is important to note that many tropical forages are low to deficient in zinc.

Q. When there is a severe deficiency in minerals in the soil, which is not only reflected in low animal productivity but also in low performace of crops, what do you recommend about meeting the animal's mineral deficiency through correction of mineral deficiency in crops so that we could kill two birds with one

stone?

A. There is a low relationship between soil analysis and plant nutrient composition. Soil analysis usually relates to the top soil which is very variable and unstable. Better correlation has been established between subsoil and nutrient content for fertility predictions. This depends on the economics. Some of the minerals such as cobalt and selenium are not required by plants but are required by animals, and thus should be supplemented directly.

Providing minerals for animals through fertilization is an acceptable method and used successfully in various parts of the world. An advantage of this method is that uniform mineral consumption by forages is obtained since the main disadvantage of "free choice" mineral supplementation is inadequate consumption of minerals by some animals. The reason mineral fertilization is not widely practiced is economics. It is more economical to provide minerals directly to animals than through the high cost of mineral fertilization. This is particularly true for extensive grazing systems. The predominant viewpoint is to use pasture fertilization if this will result in increased forage yield which can be used. Also, it is important to realize that forage mineral requirements are quite different from those of animals. Animals need, for example, cobalt, selenium and iodine while plants do not—or at an extremely low level.

Q. For mixed farming systems, crop residue grazing is usually important. At Kaduna, we have attributed increased estrus activity during the period of residue grazing through improved mineral nutrition from crop residue due to the application of fertilizer. Is this plausible? That is, do we kill two birds with one stone fertilizing soil for crops and the effect they have on animals?

A. Crop residues can be beneficial in providing minerals in addition

to the intended energy and protein provided. An effect of certain mineral deficiencies (that is, phosphorous, sulphur, and cobalt) is to reduce feed consumption. Some of the reproductive benefits from phosphorous supplementation have been attributed to the animal reducing consumption and thus having inadequate energy and protein. Therefore, a phosphorous deficiency is lowering reproduction by causing an energy-protein deficiency. Fertilizer will increase the content of certain minerals in crop residues.

Q. Why is availability of minerals in the soil a poor indicator of availability of these minerals in plants?

A. Most soils have adequate concentrations of specific minerals to prevent deficiencies. However, soil factors are more important in influencing forage mineral uptake than are concentrations of minerals in the soil. Mineral elements in forages are dependent upon the interaction of a number of factors including soil, ph, drainage, plant species, stage of maturity, yield, pasture management and climate. A number of studies in tropical countries and elsewhere have shown a very poor correlation between soil and forage mineral concentration.

Q. In most conditions under which livestock are raised, we find there are deficiencies of one or more minerals. Would it be advisable to use a complete mineral supplement (shot gun approach) rather than to conduct numerous tests to determine a specific deficiency?

A. Yes, providing a complete mineral supplement (shot gun) is the most practical way of eliminating mineral deficiencies. In Table 4 of my presentation, the characteristics of a "good" free choice, complete mineral supplement (shot gun) are given. Free choice mineral mixtures are designed to cover a wide range of environments and feeding regimes and contain a margin of safety as an insurance against a deficiency. There is little danger of toxicity or excessive cost in relation to the high probability of increased production rates for cattle from these mixtures if

formulated according to recommendations. Copper and selenium would be the minerals of most concern for toxicity. However, cattle, contrary to sheep, are much less sensitive to copper toxicity and inorganic forms of selenium (that is sodium selinite) are not well utilized by livestock when administered in excess of the requirements.

ANALYSIS OF DATA FROM ON-FARM EXPERIMENTS

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INTRODUCTION

Applied agricultural experiments are conducted in order to provide information that will be useful to farmers. Therefore, since the population to which inferences are to be made consists of individual farms it is obvious that on-farm experiments will yield results that will be more applicable to the general population of farms than experiments conducted at a central experiment station. When on-farm experiments are properly designed the researcher can evaluate the importance of farm by treatments interactions.

The conducting of on-farm experiments, however, can often be frustrating to the researcher since he does not have complete control of the experimental conditions. Because of this the data collected from such experiments will usually require more careful analysis than experiment station data. Disproportionate subclass frequencies often exist and therefore general least squares procedures must be used to analyze data from such experiments. The purpose of this paper is to first describe two basic designs for on-farm experiments and second to point out some of the most common errors made when analyzing data with disproportionate subclass frequencies.

EXPERIMENTAL DESIGNS

The first experimental design to be considered is a crossclassification design where the treatments to be compared are crossclassified with farms, i.e., each treatment is applied on each farm. In addition to the effects of farms and treatments it will usually be necessary to consider other fixed sources of variation, such as age of animal, time of measurement, sex, etc., in the analysis of the data. The general statistical model under which data collected under this design should

be analyzed is as follows:

$$y_{ijkl} = \mu + f_i + T_j + (fT)_{ij} + F_k + e_{ijkl} \qquad [1]$$

$i = 1, 2, \ldots, p$

$j = 1, 2, \ldots, q$

s = no. filled FT subclasses

r = degrees of freedom for other fixed effects

where: y_{ijkl} is the dependent or response variable.

μ is the overall mean with equal subclass frequencies.

f_i is the effect of the ith farm. Note: in order to make inference to other farms it is necessary that the farms on which this experiment is conducted be a random sample of farms.

T_j is the effect of the jth treatment.

$(fT)_{ij}$ are the interaction effects.

F_k refers to all other fixed sets of effects that may need to be considered.

e_{ijkl} are the errors that are assumed to be random and independent.

The least squares analysis of variance is given in table 1. The R ( ) values in the table refer to "reductions in sums of squares" due to fitting the constants shown in parenthesis. In the expected mean squares σ_e^2, σ_f^2 and σ_{fT}^2 are variance components for error, farms and the farm x treatment interaction and κ_T^2 and κ_F^2 refer to quadratics for fixed sets of effects.

Note that with unequal subclass frequencies there is no exact test of significance for treatment effects since $k_3 \neq k_2$, in this case. Nevertheless, if the farm x treatment interaction effects exist a more accurate test for the significance of treatment effects is obtained by

using the farm x treatment mean square as the error term instead of the remainder mean square.

Table 1. Least Squares Analysis of Variance for Data Collected Under Design 1.

Source of Variation	d.f.	S.Sqs.	E(MS)
Farms (F)	p-1	$R(\mu,f,T,F)-R(\mu,T,F)$	$\sigma_e^2+k_5\sigma_{fT}^2+k_6\sigma_f^2$
Treatments (T)	q-1	$R(\mu,f,T,F)-R(\mu,f,F)$	$\sigma_e^2+k_3\sigma_{fT}^2+k_4\kappa_T^2$
FT	s-p-q+1	$R(\mu,f,T,fT,F)-R(\mu,f,T,F)$	$\sigma_e^2+k_2\sigma_{fT}^2$
Other Fixed Effects	r	$R(\mu,f,T,fT,F)-R(\mu,f,T,ft)$	$\sigma_e^2+k_1\kappa_F^2$
Remainder	n...-s-r	$y'y-R(\mu,f,T,fT,F)$	σ_e^2

Another common design for on-farm experiments is where only one treatment is used on each farm. Under this design several randomly chosen farms are selected to receive treatment 1, several other randomly chosen farms are chosen to receive treatment 2, etc. Hence, the farm effects are "nested" within the treatment effects. With other fixed effects that may need to be considered the model underlying the analysis of data collected under this design is as follows:

$$y_{ijkl} = \mu + T_i + f_{ij} + F_k + e_{ijkl} \qquad [2]$$

$i = 1, 2, \ldots, p$

$j = 1, 2, \ldots, q_i$

s = no. filled TF subclasses

r = degrees of freedom for other fixed effects

where: y_{ijkl} is the dependent or response variable.

μ is the overall mean with equal subclass frequencies.

T_i is the effect of the ith treatment.

f_{ij} is the effect of the jth farm in the ith treatment.

F_k refers to all other fixed sets of effects.

e_{ijkl} are assumed to be random errors.

The least squares analysis of variance for data collected under this design is given in table 2. Under this design the appropriate error mean square for testing the significance of treatment effects in Farms: Treatments. However, if unequal subclass frequencies exist $k_3 \neq k_2$ and the F test for treatment effects will be approximate. Since farm effects are likely to be large in most cases this design will give considerably less accurate estimates of treatment differences when the same numbers of farms and treatments are used. If it is necessary to use this design the investigator should plan to use many more farms than would be required if the first design could be used.

Table 2. Least Squares Analysis of Variance for Data Collected Under Design 2.

Source of Variation	d.f.	S. Sqs.	E(MS)
Treatments (T)	p-1	$R(\mu,T,F)-R(\mu,F)$	$\sigma_e^2+k_3\sigma_{f:T}^2+k_4\kappa_T^2$
Farms:Treatments (F:T)	s-p	$R(\mu,T,f,F)-R(\mu,T,F)$	$\sigma_e^2+k_2\sigma_{f:T}^2$
Other Fixed Effects	r	$R(\mu,T,f,F)-R(\mu,T,f)$	$\sigma_e^2+k_1\kappa_F^2$
Remainder	n..-s-r	$y'y-R(\mu,T,f,F)$	σ_e^2

COMMON ERRORS IN USING LEAST SQUARES METHODS

Many investigators seem to think that because of the ready availability of computers and computer programs for analyzing unbalanced data, there is no longer the need for learning much about the underlying theory or the detail computations involved. In fact, many authors who have used least squares methods of data analysis seem to believe there is something magic in obtaining the results from a general least squares computer program since the only information given concerning the analysis many times is simply "the data were analyzed by the method of least squares". This, of course, is not sufficient. The author must explain why a particular model was used and he should discuss limitations involved in the analysis and interpretation of results. To do this adequately, he must understand exactly what computations are

being completed by the computer program being used.

Selection of the model

Perhaps the most common error made by researchers who are analyzing field or survey type data where unequal subclass frequencies exist is the use of an incorrect model. The most common incorrect model is one that fails to include some of the important sources of variation. If the data being analyzed are balanced with respect to the extraneous sources of variation only the error term will be biased but with unbalanced data the treatments means, sums of squares and tests of significance will all be biased.

When the model used for the analysis contains sources of variation which have essentially no effects the only consequence is a loss of degrees of freedom for the error mean squares if one has balanced data. However, with unbalanced data one not only loses degrees of freedom from error but less accurate estimates of other effects included in the model will be obtained. This loss of accuracy can be considerable in some cases. Hence, when disproportionate subclass frequencies exist or if individual class regressions are being fitted for continuous independent variables it is important to eliminate those sources of variation with negligible effects.

The procedure that should be followed to find the most appropriate model is as follows: (1) make a list of all potential sources of variation including covariates and individual class regressions, (2) analyze the data under the "complete" model, (3) omit the least significant source of variation provided $p > .2$, (4) reanalyze the data under the reduced model and (5) repeat (3) and (4) until all remaining sources of variation are significant $p < .2$. When an investigator is concerned with several dependent variables it may be necessary to compromise this procedure somewhat in order to save computing time and also to compare results obtained for different dependent variables.

Many times an incorrect model is used because the investigator has made

the analysis fit a particular computer program that is available to him rather than finding a program (or perhaps developing a program) to complete a more appropriate analysis. As computer programs are developed for completing more general least squares analyses this problem should become of less importance. Also, many times the program being used by an investigator has options available that, if used, would give a more appropriate analysis. No computer program will do anything more or anything less than it is instructed to do by the user. Therefore, the investigator must be thoroughly familiar with the capabilities of any program being used in the analysis of a set of data. Delegating this resposibility to a statistician or a technician will often result in incorrect analyses.

Assumptions underlying a least squares analysis

When all sets of effects included in the model are fixed, other than the error term, there are three basic assumptions, (1) the errors are random and independent, i.e., uncorrelated both within and between treatment groups, and the errors are normally distributed, (2) the error variance is homogenous and (3) with disproportionate subclass frequencies, it is assumed that the frequencies are uncorrelated with effects, i.e., missing observations are assumed to have occurred at random.

When data are analyzed under a random or mixed model the same assumptions as given above for the fixed linear model are required. However, under these models there are other assumptions with which the investigator must be aware. With ordinary least squares analysis, one must assume that within each set of random effects no correlations exist among the effects. Correlations existing among sets of random effects are assumed to be solely due to disproportionate subclass frequencies and sets of fixed effects must be randomly distributed across random classes or subclasses.

The theoretical assumptions described above are seldom, if ever, entirely correct especially in analyses of field or survey data.

Therefore, it is important that the investigator make every effort to determine how invalid assumptions may have affected the results being reported.

Making tests of significance

A user of the General Linear Model Procedure (GLM) in the Statistical Analysis System (SAS) may obtain four types of sums of squares. When using this procedure one must be careful to choose the appropriate sums of squares for the analysis being completed. Otherwise, serious errors will result in interpretation. In order to select the appropriate results from the output one can obtain from GLM, the user must be thoroughly familiar with the manner in which the computations are being made. For example, one must understand that the Type I sums of squares are model-order-dependent, i.e. sequential in that each sum of squares given is adjusted for unequal subclass frequencies for the preceding effects in the model. The sums of squares for main effects that are given for Type II are unadjusted for interactions involving those main effects. Also, if B effects are nested within A effects, then the Type II sum of squares for A are unadjusted for the B effects. Oftentimes, when analyses are being completed under mixed models use should be made of some of the Type II sums of squares. Analyses completed under the fixed linear model should use only Type III sums or squares. Type IV sums of squares are seldom, if ever, of any use to an investigator.

When data are being analyzed under a mixed model and there are disproportionate subclass frequencies a program that is designed for the analysis of this type of data should be used, e.g., Harvey's LSML76 or LSMLMW programs (1977, 1982 and 1985).

As shown in tables 1 and 2, more than one error term is required to complete the tests of significance in most analyses completed under a mixed model. In order to be sure one is using the most appropriate error term in making a test of significance it is necessary to have available the expected mean squares.

The F test in an analysis of variance for a fixed set of effects, such as "treatments", is of little value if one has more than two treatment groups to compare. In this case, the investigator should select the treatments so that an orthogonal set of individual degree of freedom comparisons will answer the questions for which the experiment was designed. Linear contrast options should then be used to make the specific test of significance desired. If the treatment groups represent levels or time the investigator should be interested in fitting orthogonal polynomials. In factorial experiments where there are two factors each at several levels one should be interested in finding the best fitting surface. This means that the interaction degrees of freedom should be partitioned into linear x linear, linear x quadratic, linear x cubic, etc.

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SUMMARY OF GROUP ONE DISCUSSION

ON-STATION RESEARCH (OSR)

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THE ROLE OF OSR

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

GENERAL GUIDELINES FOR OSR

1. Research should be oriented to farmers' needs obtained from ex-ante analysis or from OSR surveys.

2. OSR should consider national policies. One way to facilitate communication would be to include those who set policy in the group setting research priorities. If national policies seem to need change, then involvement of policy makers in bodies like TAC would assist this.

3. OSR should be coordinated with research at other research institutions (universities, ministries of agriculture or extension services). This should be done to avoid duplication and because of limited manpower and other resources.

4. OSR is multidisciplinary. The design of the study should incorporate the views of the whole team. A statistician should assist design to ensure that the resulting data may be analyzed usefully.

5. A tie to extension is necessary.

AREAS OF CONCENTRATION FOR OSR WITH LIVESTOCK

1. Nutrition. This is the major constraint to improving production and should be given first priority.

a) A characterization of available feedstuffs should be made, and researchers should use them to formulate new diets or to adjust existing ones. New enterprises should be tested first in OSR. These include feed processing (grinding, mixing and additions), mineral supplementation, and feeding products to assure intake.

b) Forage crop screening is crucial: livestock OSR should stress the development and utilization of forage just as agronomists stress cereal production for human consumption. Given the human food deficit, it is important to maximize animal production while minimizing use of cereals in livestock rations.

c) Physiology: because many animals are required for this research, it is sometimes necessary to obtain these numbers through research off-station. Basic research should be conducted with OSR. Many of the recent highly sophisticated advances in physiology (e.g., oestrus synchronisation, embryo transplant and genetic engineering) should be left to more advanced research stations. In situations where nutrient intake is low and management skills limited, highly bred livestock will not perform well. Basic research should be done at universities or national stations.

2. Health. The choice of site (station or farm) for health trials depends on the presence of interactions between the health treatment and other factors, such as nutrition. In general, it is desirable to identify health problems in the field and to test solutions in site, partly because health problems should not be imported to stations.

3. Animal draft power. OSR should test new techniques, develop new equipments, and study interactions between the power and other components (such as cultivars and fertility) of farming systems. Suitable topics include nutritional and health problems of draft animals, work output determination, and agricultural engineering.

4. Genetic improvement. This is necessary but a low priority in view of yield gaps between station and farm results with existing breeds. For meat, selection within existing breeds is more important than crossbreeding, since meat will usually be produced from ranges with limited feed supplementation. For milk production, the necessity of increased supplementation, even if selected local breeds are used, makes crossbreeding a more attractive alternative. Improvement will be faster with crossbreeding and is recommended. The adaptability of crossbreeds should be tested on station before OFR is done with them.

DESIGN AND RESEARCH METHODOLOGY

1. If livestock trials require replicates over several years, they should be designed to produce annual reports which can serve as inputs to the trial in subsequent years.

2. While station trials should be simplified to avoid confusing results and interpretation of data, they can be more complicated than OFR designs. Any experiments requiring complicated designs or very precise measurements should be done on stations.

3. Avoid duplication of experiments. This is especially important where several entities (national and international programs, universities) are conducting research in the same country.

4. Conduct relevant analyses rather than all-inclusive, expensive analyses which may be nice to know but have little relevance to the immediate research objectives.

5. Use appropriate sampling techniques--e.g., more samples off-station than on-station are needed because of variability in off-station feeds. The use of blocking is necessary--e.g., grouping supplemented dams by age and calving history.

6. Estimates of response functions should be done on-station because of the need to control non-treatment variables. This is especially

true of feeding trials. While OFR is useful to characterize feed resources, estimating responses to those resources should be done on station.

7. Express results in economic terms, if possible, and use those results as inputs for the design of further OSR and OFR.

SUMMARY OF GROUP TWO DISCUSSION

ON-FARM RESEARCH (OFR)

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THE ROLE OF OFR

1. The first role is to give an ex-ante description of the production system and to identify relevant problems for on-station research (OSR). What are the research problems? Is the system amenable to intervention? What information about the system can be provided to OSR before it is done?

2. The second role is to verify OSR results. Is a result useful on farms? What is its real effect on farms? Is it economically and technically applicable?

3. The third role is to provide a continuing flow of information to OSR programs. That is, the flow of information from OFR to OSR does not stop after OSR has started, but continues in an iterative process.

4. The fourth is to test new technologies under farmers' conditions.

5. The fifth is to demonstrate improved technologies to farmers and to extension personnel.

GENERAL GUIDELINES FOR OFR

1. OFR scientists must have a close association with OSR scientists.

2. The objectives of OFR must be clearly defined in terms of producing information which will result in new technologies.

3. Technical, economic, and social effects are inseparable. Attempts to study one effect in isolation from the others will lead to misleading results.

4. Extension contacts are vital from the start. They are used to facilitate relations with farmers and to encourage input from extension workers when OFR is being designed.

AREAS OF CONCENTRATION FOR OFR WITH LIVESTOCK

1. Feeding trials.

a) Are responses similar to those found with OSR? When a norm of farm responses is found in a region, then OSR results and recommendations can be adjusted for this norm.

b) How do the management implications of feeding recommendations fit into farmers' systems? This is relevant not only to the level of response to a given feed, but to other factors associated with the use of that feed, such as its current allocation to other purposes (e.g., crop residues used for fuel).

c) Are the technically optimal feeds available in the target region? Does their diversion to feeding incur significant costs?

d) Large scale screening of forage cultivars should not be done on farms, because such screening requires environmental and management uniformity. Multilocational trials of selected cultivars can be done if there is previous experimental evidence that they are superior under a wide range of conditions.

2. Adaptive health trials. This should only be studied on farm in conjuction with nutrition or management trials. For some diseases (e.g., rinderpest) it is an all or nothing situation, and can be done on station. For other diseases (e.g., parasites) where there is a strong interaction with nutrition or with management, an OFR problem exists. Trials which pose risks to farmers, such as drug tests, or which are likely to be executed poorly, such as those requiring farmers to separate their own animals into control and treated groups, should be carefully selected and only used when station trials have been done previously.

3. New enterprises. There were many examples of these noted, such as

dual purpose goats in western Kenya, cow traction, single ox traction, and scoops in Ethiopia. OFR with new enterprises will often expose farmers to opportunities beyond their immediate experience, and thus provide valuable information for both researchers and farmers. However, it was agreed that basic testing of new enterprises must be done on station and that rapid introduction of new enterprises by OFR can only be done where there is a good experimental base. As with health trials to be done on-farm, experiments involving risks should be done as much as possible on station.

4. Animal power. While this is a special case of new enterprises, it is important enough to merit separate mention. Measurement problems (e.g., cultivation depth, work output) make some types of animal draft OFR difficult. Studies of energy use and of agricultural engineering are best done on station. Grosser measures of output, such as area cultivated, can be done on farms, but only after the basic animal draft technology has been demonstrated on station. Special aspects of animal power work (such as feeding or health problems) should be treated in the same manner as the general approach to feeding or health noted in 1 and 2 above.

5. Resource surveys and allocation. These are important for extrapolating OSR results over wide areas, and for aiding the design of further OSR. The use of models for such extrapolation depends very much on results of resource surveys.

6. Research/extension. There is need to incorporate research methods into the extension system to support the adoption of interventions; it is recognised that this procedure must not lead to situations which render the recommendations artificial.

DESIGN AND RESEARCH METHODOLOGY

1. Types of trials. Types of trials in OFR are usually classified by the degree of farmer control. These range from demonstrations in which there is no farmer control to farmers' tests in which the farmer does

everything. There are general principles that there is greater inherent variability in OFR as the degree of farmer control increases, and that farmer control becomes more necessary as the technology gets closer to the extension stage. This variability will increase the need for replicates at each site; therefore, one expects sample size and total trial cost to be positively associated with the degree of farmer control. All other things remaining constant, the necessity for replicates across farms or sites will be increased if replicates within farms are not possible.

Livestock on-farm trials may require more care in experimental design, as explained in Gryseels' paper. Therefore, trials with a high degree of farmer control need to be planned carefully, in order to avoid execution or interpretation errors which would invalidate the results.

2. Level of quantification. This is a function of the purpose of the OFR. Resource allocation surveys--cropped area, stocking rates, labor availability--can be done very accurately in some cases, but there are variables (such as milk or crop yield) which are more difficult to survey accurately. It is clear that (a) the level of quantification must be decided upon, at the start, with due regard for statistical consideration; (b) every variable measured must be justifiable by the research objectives; (c) cost considerations are important in deciding which variables to measure and how to measure them; and (d) farmers' estimates of treatment effects are useful, but they must always be complemented by objective measures.

3. Types of analysis. This is a function of the level of quantification. Since one of the precepts of OFR is the necessity of technical, economic, and social analyses, it follows that the data collected must permit these analyses. As a minimum, three analyses should be possible with any OFR: (a) technical--What is the physical effect (e.g., change in milk yield) of the treatment tested?; (b) economic--What is the economic effect of the treatment? It should always be possible to make enterprise budgets from the technical data and from knowledge of prices of inputs and products; (c) social--What

is the social effect of the intervention? What interactions would the successful adoption of the intervention have with the social systems? Are those interactions impediments to adoption? For example, with increased milk production, would producers be able to find outlets for the milk?

4. Adoption. Some index of adoption must be devised, but this is only necessary when true adoption takes place. This will generally be after a long sequence of OSR and OFR. Biased indices--those which report adoption under very high levels of research or extension input--must be reported with care.

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