AGRICULTURAL RESEARCH IN TANZANIA

By

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement

Over the years the Government of Tanzania has recognized the need for modern technology to increase agricultural production. Since the colonial period, agricultural research institutions have been established to cover most of the ecological zones of the country and research has been carried out on major crops by these institutes. However, recently critics have raised the question as to whether this research has been consistent with the needs of the majority of farmers (Collinson, 1980). Closely related to this is the question of how effective the research findings have been communicated to the farmers. These questions have been raised due to the persistently low agricultural productivity and the use of traditional methods of farming, despite all the research that has been done in the country. This paper focuses on agricultural research in Tanzania. Its intention is to suggest ideas for further investigation into how to increase the effectiveness of the research system.

1.2 Objectives of the Study

This paper describes the evolution and major constraints faced in conducting agricultural research in Tanzania. The specific objectives of the study are to:

1. Identify the major constraints to agricultural research.
2. Examine the potential for the application of the Farming Systems Research approach.
3. Determine some of the analytical issues to be considered in agricultural research.
4. Identify relevant analytical models to assess new technology for small farmers.

1.3 Background Information

1.3.1 Land and Population

The United Republic of Tanzania has a total land area of about 945,090 sq km. Only about 5 percent of the total land area is used for crop production (FAO, 1984). About 44 percent of the total land area is forest and wood land, vegetation which is a costly barrier to agricultural development. The cost of clearing this land is high in relation to the poor and uncertain yields. Another consequence of this vegetation is the spread of Tsetse fly (Bureau of Statistics, 1970). Animal husbandry is possible only with constant and careful veterinary supervision (Ruthenberg, 1964). Presently, research is going on at the Tanzania Pesticide Research Institute (TPRI) for the control and eradication of Tsetse flies.

The population of Tanzania is about 21.7 million (FAO, 1984). Between the 1967 and 1978 census the population growth rate was estimated at 3.2 percent [1] (Bureau of Statistics, 1982). The population is concentrated along the coast, in the rainy highlands of the south, around mountain Kilimanjaro and mountain Meru, and along the shores of Lake Victoria (Ruthenberg, 1964). The thinly populated central part is relatively dry and infertile.

1.3.2 Rainfall and Irrigation

Most of Tanzania has a dry climate, especially the central part. Heavier rains occur in the northern and southern highlands (Map. 1). Ruthenberg (1964) described the pattern of rainfall as follows:- about one third of the country receives enough rainfall to support agriculture fairly adequately (95 percent or more chance of 762 mm). Another third receives sufficient rain for bush and grass only (less then 85 percent chance of 508 mm). The remaining third of the country falls somewhere between these two. This is considered marginal land where cultivation is possible, but the average yields are relatively low and vary greatly from season-to-season.

The rainy season usually occurs during October/November to May - although in some parts, especially on the coast, a distinction is made between the short rains of November and December and the long rains from March to May. Between May and October is a long dry spell (Bureau of Statistics,

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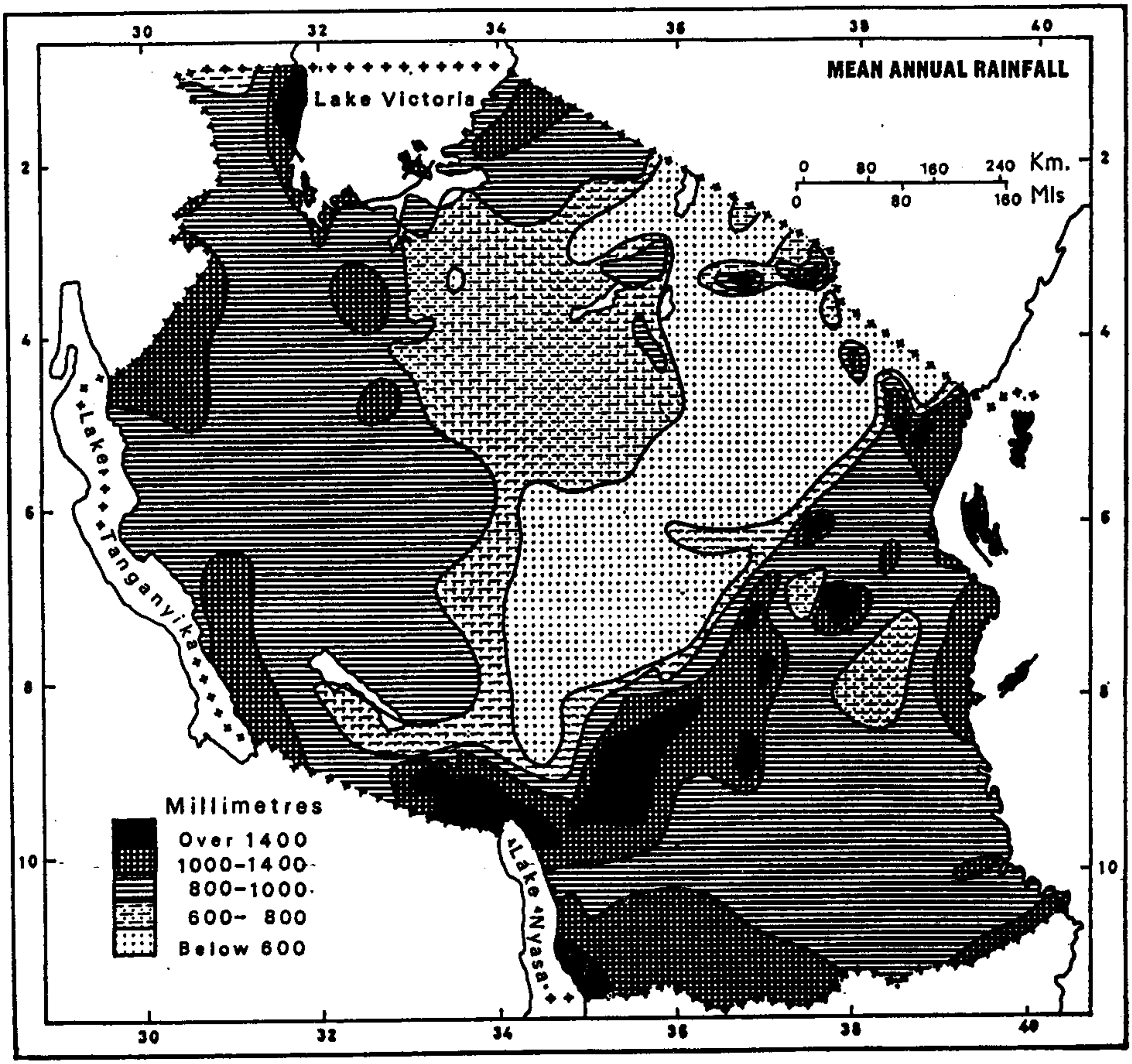
1. In the 1967 census the population was 12,313,469 and in the 1978 census it was 17,512,610.

MAP 1: MEAN ANNUAL RAINFALL IN TANZANIA



Source: Berry, (1971).

1970). The main problem is that generally, rainfall is unreliable. It fluctuates greatly from year-to year and from month-to-month. Sometimes the rain falls with great intensity. As much of it can not be quickly absorbed by the soil, erosion is likely. However, in the highland regions (e.g., Mbeya and Kilimanjaro) rainfall is more evenly distributed (Ruthenberg, 1964).

The scope for irrigation is very extensive in Tanzania. Potential irrigable land is estimated at 933,000 hectares (Table 1).

Table 1. SURVEYED AREAS (Ha) WITH IRRIGATION POTENTIAL TANZANIA, 1980.

Basin/Area	Area Suitable for Irrigation (Ha)
Rufiji River Basin	700,000
Smith Sound	88,000
Wami River Basin	32,000
Lake Victoria Basin	29,000
Ruvu Basin	20,000
Kagera River Basin	20,000
Ngono River Basin	16,000
Luiche River Basin	10,000
Pangani River Basin	10,000
Ruvuma River Basin	8,000
Total	933,000

Source: Government of Tanzania, 1983

The present area under partial and full scale irrigation is approximately 144,000 hectares, with traditional small-holder irrigation accounting for 120,378 hectare of the total (Government of Tanzania, 1982). The National Agricultural Policy Final Report (Government of Tanzania, 1982) noted four problems which have hindered rapid progress of irrigation on a wide scale :

1. Absence of an irrigation policy.
2. Reliance on sophisticated irrigation techniques which demand heavy investment, highly trained manpower and a large foreign exchange component.
3. Lack of experienced manpower to design and construct large scale irrigation schemes.
4. Poor planning of irrigation projects, particularly the peasants' irrigation schemes.

1.3.3 Agriculture

Agriculture in Tanzania contributes about 50 percent of the country's Gross Domestic Product (GDP) and about 90 percent of the total population is directly or indirectly engaged in agriculture. Tanzania is therefore predominantly an agricultural country. The dominant position of agriculture is shown in the estimates of GDP (Table 2).

The main food crops grown in the country include maize, cassava, sorghum/millet, rice, beans, and bananas.

1. Maize: This is the most important staple food grain and is produced by more then 50 percent of Tanzania farmers (Government of Tanzania, 1982). Only the surplus not required for home consumption enters the market channel.

Table 2: Gross Domestic Product at Factor Cost by Industrial Origin, Tanzania.

(At Current Prices)

INDUSTRY	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Agric., Hunting, Forestry, Fishing	40.1	39.5	38.8	41.2	45.5	50.3	51.4	51.5	50.5	50.6	50.7	51.5
Mining and Quarrying	0.9	1.1	0.9	0.6	0.5	5.0	0.4	0.5	0.6	0.4	0.3	0.4
Manufacturing	11.4	11.0	10.6	10.4	11.4	10.5	12.6	11.8	11.2	10.0	10.0	9.2
Electricity and Water Supply	1.0	0.9	0.8	0.8	0.9	0.8	0.8	0.9	1.2	1.2	1.2	1.1
Construction	4.7	5.3	4.9	4.3	3.5	3.3	3.0	3.5	3.8	4.0	4.0	3.5
Wholesale and Retail trade Restaurants and Hotels	12.8	13.1	13.7	12.8	1.4	11.3	10.1	9.6	9.4	9.0	5.0	8.0
Transportation storage and communication	8.6	8.9	9.1	8.7	7.8	6.8	5.8	5.8	5.7	4.9	4.9	4.5
Finance Insurance Real Estate and Business Services	10.4	10.2	10.1	9.7	9.1	8.3	9.1	10.0	10.2	11.2	11.2	12.1
Public administration and other services	11.7	11.6	12.7	13.0	11.8	10.1	9.0	9.0	9.7	10.8	10.8	11.6
Less imputed bank service charges	1.6	1.6	1.6	1.5	1.9	1.9	2.2	2.5	2.3	2.1	2.1	1.9
GDP at Factor Cost	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Bureau of Statistics (In Jamhuri ya Muungano wa Tanzania, 1983.)

2. Sorghum/millets: These have been the traditional food grains and are mainly grown in drier parts of the country. However, these crops have been progressively displaced by maize because of extensive bird damage (Sprague et al ., 1971). Increased bird damage may be due to the fact that children who in most cases were involved in bird scaring go to school and therefore less labor is available on the farm.
3. Bananas: These are the main subsistence food crops in Kilimanjaro and Kagera regions. They are also sold locally as fresh fruit.
4. Cassava: This is widely grown as a subsistence reserve against famine and food shortage.
5. Rice: This is grown by both small-holder farmers and government owned large scale farms.
6. Beans: In most cases beans are inter-cropped with other crops such as maize, sorghum, and bananas and they are mainly used for home consumption.

1.4 Data and Information Source

Data and information will be largely drawn from the following sources:

1. Documents prepared by the Farming Systems Research Project, Tanzania, implemented jointly by the government of Tanzania and Oregon State University.
2. The Tanzania annual plan reports.

3.The Tanzania Agricultural Research Directory of 1983.

4.The Tanzania National Agricultural Policy Document of 1982.

1.5 Organization of Paper

This paper is organized into five chapters. The introduction provides some background information about Tanzania. Chapter two describes the evolution, strengths and weaknesses of agricultural research in Tanzania. The third chapter focuses on the Farming Systems Research Program in Tanzania. In the fourth chapter, several analytical procedures and models for evaluating research will be presented. Suggestions on sources of data to specify the models will also be provided. Chapter Five provides a summary and strategies for the future of FSR in Tanzania.

CHAPTER 2

EVOLUTION OF AGRICULTURAL RESEARCH IN TANZANIA

Agricultural research institutes have been established since the colonial period. This chapter provides an overview of the evolution of agricultural research in Tanzania, and is divided into four sections. In the first section, the role of agricultural research in development will be discussed. The second section will discuss agricultural research in Tanzania under the colonial rule, followed by agricultural research after independence. Finally in section four, strengths and weaknesses of agricultural research in Tanzania will be discussed.

2.1 Role of Agricultural Research in Development

It is generally accepted that carefully implemented agricultural research can be an efficient source of economic growth and is an important contributor to the achievement of key development objectives. A review of numerous studies on the returns to investment in agricultural research over a range of countries and crops shows returns can be extremely high (Cummings, 1976). Since most parts of Tanzania are now running out of good agricultural land, it is essential that agricultural research generate new technologies that will permit higher yielding crop and livestock production. Increased food production is an essential ingredient for development. It will provide for better nutrition, reduce food costs, and contribute to economic growth. Arnon (1968) identified the following primary objectives of agricultural research:

1. To increase productivity by increasing production per unit of area (or animal), or in irrigation agriculture per unit of water, if water is the limiting factor.

2. To increase efficiency by reducing the input of labour in relation to production or by making work less onerous.

3. To increase the stability of production: by breeding varieties of crops and animals that are more disease resistant or more immune to unfavourable environmental conditions, and by improving methods of crop protection against diseases and pests.

4. To improve food quality by breeding varieties with inherently higher nutritive value, improved flavour, or eye-appeal, by improving production that affects quality, and by improving post-harvest techniques.

5. To produce the types of products required for consumption, industry and export.

For the case of Tanzania, more emphasis has been placed on the objective of increasing productivity. This is because the main agricultural objective since independence in 1961 has been to achieve self-sufficiency in food production and simultaneously produce surpluses for export. Therefore, the research program has mainly focused on the problem of increasing yields per unit of area or animal unit (Government of Tanzania, 1978).

Research has also focused on increasing stability of production. For example, drought resistant maize and sorghum composites were developed (Government of Tanazania,, 1983) and work in cotton breeding produced resistance against Fusarium (Government of Tanzania, 1972). Little work has been done on the improvement of the quality of different crops, especially on the nutritive value. Unfortunately, new varieties have been developed which have an unfavorable flavor and/or eye-appeal. One example is the sorghum composite "serena", which had a reddish color whereas the preferred traditional sorghum is whitish.

Agricultural research can play an important role in improving agricultural productivity. Reliance on traditional agricultural technology may not provide enough food for Tanzanias' rapidly increasing population, growing at 3.2 percent per year (Bureau of Statistics, 1982).

The potential benefit of agricultural research will only be captured if the improved technologies are adopted by farmers. As Lele (1976) noted, research needs to be oriented to developing technological packages that are profitable - not only on research stations and demonstration plots - but also on small farmers' fields, and has to be consistent with farmers' tastes and preferences.

The potential benefits of agricultural research also depend on having an attractive economic environment, in particular remunerative prices for producers. Failure of the government to provide a suitable economic environment may discourage the adoption of new technologies (Lele, 1975).

2.2 Agricultural Research During the Colonial Era

Agricultural research in Tanzania was initiated by the colonial government. In 1902, the first research institute was started in Tanganyika[1]. This was the Amani Institute, originally founded under the German administration. During the British rule this Institute served the East African British empire (Kenya, Uganda, Tanganyika and Zànzibar). In 1929/30 the Institute established soil science, plant pathology, entomology, biochemistry, plant physiology and botany laboratories (East African Agricultural Research Station Amani, 1929-1930). Research at this time therefore tended to be basic rather than applied. In 1948, the East African Agricultural and Forestry Research Organization (EAAFRO) was founded, with headquarters in Muguga, 12 miles from Nairobi, Kenya (East African Community, 1975). The Amani Institute was then absorbed by EAAFRO. At about the same time, other regional research organizations were formed. The East African Veterinary Organization (EAVRO), East African Trypanosomiasis Research Organization (EATRO), and Tropical Pesticide Research Institute (TPRI). These regional research organizations served the three East African countries of Tanzania, Kenya,

1. Tanzania was created in 1964 by the union of Tanganyika and Zanzibar.

and Uganda. They concentrated on problems common to the three countries (East African Community, 1975).

During the colonial era, the economy of Tanzania was based on plantation crops such as sisal, cotton, coffee, cashewnut and tea. Agricultural research policy, therefore, took the same orientation (Government of Tanzania, 1982). Agricultural research stations were organized and funded on the basis of these export crops (Table 3) and research programs were aimed at solving problems facing the estate farmers. As a result, those who benefited most from early research findings were the foreign estate owners.

Table 3. Commodity Research Stations, by Crop, Tanzania

Research station	Year started	Crop
Lyamungu	1934	coffee
Ukiriguru	1950	cotton
Ilonga	1950	cotton
Mlingano	1937	sisal
Naliendele	1948	cashewnut

Source:- Government of Tanzania, 1983

During this period, agricultural research was being started, developed and run entirely by expatriate personnel with little or no knowledge of the social, economic and environmental constraints facing subsistence farmers. Research did not address subsistence farmers' problems since subsistence farming was not considered to be important.

2.3 Agricultural Research After Independence

Tanzania achieved political independence in 1961. EAAFRO and the other regional research organizations were carried over after independence. They were administered as a department of the East African Community (EAC). Research by these organizations was largely basic in nature, and the responsibility to conduct extensive applied research was left to individual countries (Government of Tanzania, 1983). In the late 1970s and early 1980s, following the break up of the EAC in 1977, each country established a new research setup. The research system in Tanzania was given parastatal status and fell under three major organizations:

1. Tanzania Agricultural Research Organization (TARO), which was started in 1980.
2. Uyole Agricultural Center (UAC), originally started in 1970.
3. Tropical Pesticide Research Institute (TPRI),[2] established in 1950 and given parastatal status in 1979.

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[2]. Former institute under EAC

The Ministry of Agriculture, however, was still responsible for the overall coordination, supervision and monitoring of agricultural research in the country. In 1980, a separate Ministry of Livestock was established. This meant the separation of crop and livestock research programs. Subsequently, the Tanzania Livestock Research Organization (TALIRO) was established to carry out livestock research. From the FSR perspective it can be advantageous to have livestock and crop research under the same organization. In this way the interrelationships betweeen livestock and crops can be dealt with more efficiently.

During the post-Independence period, agricultural development in Tanzania has emphasized diversified crop production and the integration of cash crops with food crops (Government of Tanzania, 1982). This strategy was aimed at achieving self-sufficiency in food production and simultaneously producing surpluses for export. Agricultural research was therefore re-shaped to take into account the new strategy. Research was directed towards both food and cash crops, as well as livestock. There has also been an effort to serve the needs of small-holder farmers rather than large scale producers. However, the pre-independence focus of conducting all research on the experiment station was not changed (Government of Tanzania, 1982).

2.4 Strengths and Weaknesses of Agricultural Research in Tanzania

2.4.1 Weaknesses

Despite all the research which has been done in Tanzania,food crop yields has not changed significantly over a long period of time (Table 4).

Table 4. YIELD (Kg/Ha) OF SELECTED CROPS, TANZANIA, 1974-1984

Year	Crop				
	Maize	Sorghum	Millet	Rice	Beans (dry)
1974	1200	700	1201	1560	500
1975	750	848	727	1154	500
1976	690	776	650	1229	497
1977	747	727	682	1386	509
1978	801	714	727	1300	255
1979	557	629	727	1300	500
1980	577	629	729	1433	533
1981	692	629	636	1333	500
1982	597	704	829	1404	500
1983	800	697	838	1481	458
1984	905	692	814	1481	458

source: FAO Production Yearbook,1984, 1981, 1980, 1977, 1975

This can be partly explained by the weaknesses of agricultural research. Factors which contribute to the unsatisfactory performance of agricultural research are (Government of Tanzania, 1982):

1. Lack of policy direction in research
2. Shortage of trained manpower and administrative capacity
3. Insufficient funds
4. Inefficient coordination between research bodies
5. Absence of research - extension linkage
6. Emphasis on station based research, as opposed to farm based research.
7. Emphasis on biological research
8. Documentation and dissemination of research information is either poor or non-existent.

Each of the above weaknesses is briefly discussed below.

1. Lack of Policy Direction in Research

The past agricultural research programs indicate that, for a variety of reasons, the planning and organization of such programs have been inadequate. Research priorities have been determined on an ad hoc basis (Government of Tanzania, 1970). Sprague et al. (1971) recognized that there is a need for a well defined national program for agricultural research that establishes research priorities, so that research resources are allocated to problems of greatest importance. To plan priorities and strategies for agricultural research, data are needed on rainfall patterns, present and past yields, erosion and soil fertility, socio-cultural factors and the budgetary requirements for a given level of research effort. Priorities set without such data may misdirect research efforts. Research priorities must also be consistent with the overall national objectives, and the needs of the majority of people in the country.

2.Shortage of Trained Manpower

Research efforts in Tanzania are constrained to a large extent by the shortage of qualified personnel. Lack of qualified personnel sometimes results in having staff without professional work experience assigned as major research or section heads, or given major responsibility for important projects with virtually no supervision.
Table 5 show the number of graduate research personnel in Tanzania. As related to the 1982 population, it shows that the ratio of the graduate personnel to the total population was about 1:81,000.

3.Insufficient Funds

Research in Tanzania has generally been underfinanced. Funding of research is mainly allocated by Parliament through the Ministry of Agriculture. Actual allocations for research seldom equal requested funding. Mmbaga (1983) observed that the final approved budget was almost always less then 50 percent of the original requests. Of this almost 70 percent is spent on personnel compensation.

Therefore, only 30 percent is devoted to research and institute operations. The absence of funds at critical stages of research has sometimes led to abandoning experiments (Mmbaga 1983). Together with insufficient funding, Mbilinyi (1973), observed delays in getting funds allocated to specific research stations in time for implementing research plans.

Table 5. TOTAL NUMBER OF GRADUATE STAFF AT RESEARCH STATIONS BY DSCIPLINE TANZANIA, 1982

Discipline	Percent	Number
Agronomy	25	58
Breeding	19	44
Soil Science	14	34
Entomology	9	22
Plant Protection	7	17
Pathology	7	16
Agric. Engineering	3	8
Chemistry	3	7
Agric. Economics	3	6
Land Use/Management	3	6
Botany	2	4
Extension	2	4
Biometrics	1	2
Food Technology	1	2
Nematology	1	2
Administration	1	2
Physics	*	1
Documentation	*	1
Total		236

* = Less than 1 percent

Source: Government of Tanzania, 1983

4.Insufficient Coordination Among Research Bodies

Agricultural research in Tanzania is fragmented between the Ministry of Agriculture and parastatal organizations (Government of Tanzania, 1982) with little coordination between these organizations. Sokoine University of Agriculture also conducts crop and livestock research, independent of the other institutes. Such fragmentation of research without proper coordination is a big constraint to agricultural research in Tanzania. This may lead to duplication of efforts (Mmbaga, 1983), which can be very costly given that resources are scarce (especially trained personnel and funds).

5.Absence of Research - Extension Linkages

Links between research and the farming community are essential if research findings are to contribute to agricultural progress. The extension worker is the logical agent for this purpose (Arnon, 1968).

The agricultural extension services were designed in Tanzania to fill the gap between researcher and farmer. By 1977 there were about 6,500 available extension staff, representing a ratio of 1:700 farm families (Government of Tanzania, 1982). This shortage of extension staff is not a major factor explaining the lack of linkages between research and extension. One of the main factors is that the extension staff has not been involved in planning and evaluating research activities. There has not been effective communication between research and extension (Mbilinyi 1973). The researcher has not received information relevant to farmer circumstances from the extension staff, and the extension staff did not get the information about research results to be communicated to the farmer. For this reason researchers did not develop technology which was suited to resource poor farmers in Tanzania. As a result of this, a gap was created between the researcher and the farmer. Research findings tended to be confined within the research station boundaries, and could not be adapted to the conditions of small farmers, while the farmers' problems did not reach the researcher.

Various factors have a negative effect on the transmission of information between extension and research. Extension workers frequently see researchers as being shut up in their laboratories, giving little attention to social and economic factors, using obtuse language, and carrying out research without any application in mind (Compton 1982). On the other hand, research scientists see extension workers as being unwilling to trust or accept research findings, unwilling to ask research scientists for information when it is needed, not helping to clarify the nature and extent of field problems that need researching, and demanding immediate answers to urgent problems that in fact call for longer periods of time to work out solutions (Arnon, 1968).

Such misunderstandings between researcher and extension staff can greatly be minimized if the two can work together. For example the fact that in Tanzania research and extension are under different organizations contributes a great deal to this problem. Since the objective of both research and extension should be to improve the welfare of the rural community, it is important that efforts of the two be mutually reinforcing (Government of Tanzania, 1970).

6.Emphasis On Research Station Based Research as Opposed to Farm Based Research

The history of agricultural research in Tanzania reveals that most research has been done at research institutes and their satellite stations (Government of Tanzania, 1972). Work at these stations has been centered around agricultural scientists organized into disciplinary specialties or along commodity lines. The key questions about this kind of research are:

1. Whether the main problems facing small farmers were addressed by such research.
2. If the new technologies developed by the researcher were appropriate under the farmers' social, economic and physical conditions, and

3.If at all the new finding reached the farmers.

Realizing this weakness of agricultural research, the Tanzania National Agricultural Policy (Government of Tanzania, 1982) recommended that agricultural research should take a farm-centered, problem-solving approach for on-farm testing to arrive at relevant extension packages; and research must take place with the full support of farmers who best know the problems confronting them. Research institutes should have balanced station based and on-farm research programs.

The emphasis here is on farmer participation and farm based research. There is a need for a two-way flow of information between on-farm work and research at experiment stations, and an active horizontal flow of information across scientific disciplines (Gostyla and Whyte, 1980).

7.Emphasis on Biological Research

By reading through the Directory of the Agricultural Research Institutes (Government of Tanzania, 1983), one can find that the major research activities for most of the research institutes include plant breeding, agronomy, pathology, entomology, soil research and the like. Except for Uyole Agricultural Center (UAC), which has an agricultural economics and rural sociology department, and Ilonga Research Institute with a farming systems research unit;

research in Tanzania is largely biologically oriented. Mbilinyi (1973), elaborating on this problem, said:

> ...when a scientist is asked a simple question about how much the farmer has to pay in order to adapt the research recommendations, most researchers do not have satisfactory answers. If one probes even further by inquiring about the acceptability of his recommendations to the small farmers, the scientist will shrug his shoulders and say that, such issues are the work of the extension man.

This weakness is also demonstrated by the disciplines of the graduate staff at research stations (Table 4). Of the total number of the graduate staff 58 percent are agronomists, plant breeders and soil scientists. To develop an integrated approach to agriculture, and to have a farmer perspective in research, it is generally accepted that a wider variety of disciplines is necessary for doing problem-solving research. It is certain that future agricultural research programs must focus on social and economic aspects, as well as on technical considerations (World Bank, 1981).

8. Documentation and Dissemination of Research Information is either Poor or Non-Existent

As has been mentioned earlier, agricultural research in Tanzania is carried out by various bodies. The major documents of these institutes are the annual, quaterly or monthly research reports. The circulation of these reports between institutes is very limited. As a result the flow of information between institutes is minimal, and an unnecessary professional isolation is created among scientists. Table 4 shows that there has been only one staff member responsible for documentation among all the research stations. Greater allocation of resources to documentation would serve to diffuse research results and increase the impact of funds and other resources invested in research projects. Sprague et al. (1971) suggested the introduction of technical and non-technical research publications to facilitate communications between scientists and also between researchers and farmers.

2.4.2 Strengths

Very little exists in the literature on the strengths of agricultural research in Tanzania. This could be partly due to inadequate documentation of the research findings. Despite all the weaknesses, some strengths of the agricultural research system are the location of research stations to represent each ecological zone, links to international research organizations, and some success in the generation of improved material or knowledge.
Below is a brief discussion of each of the above strengths.

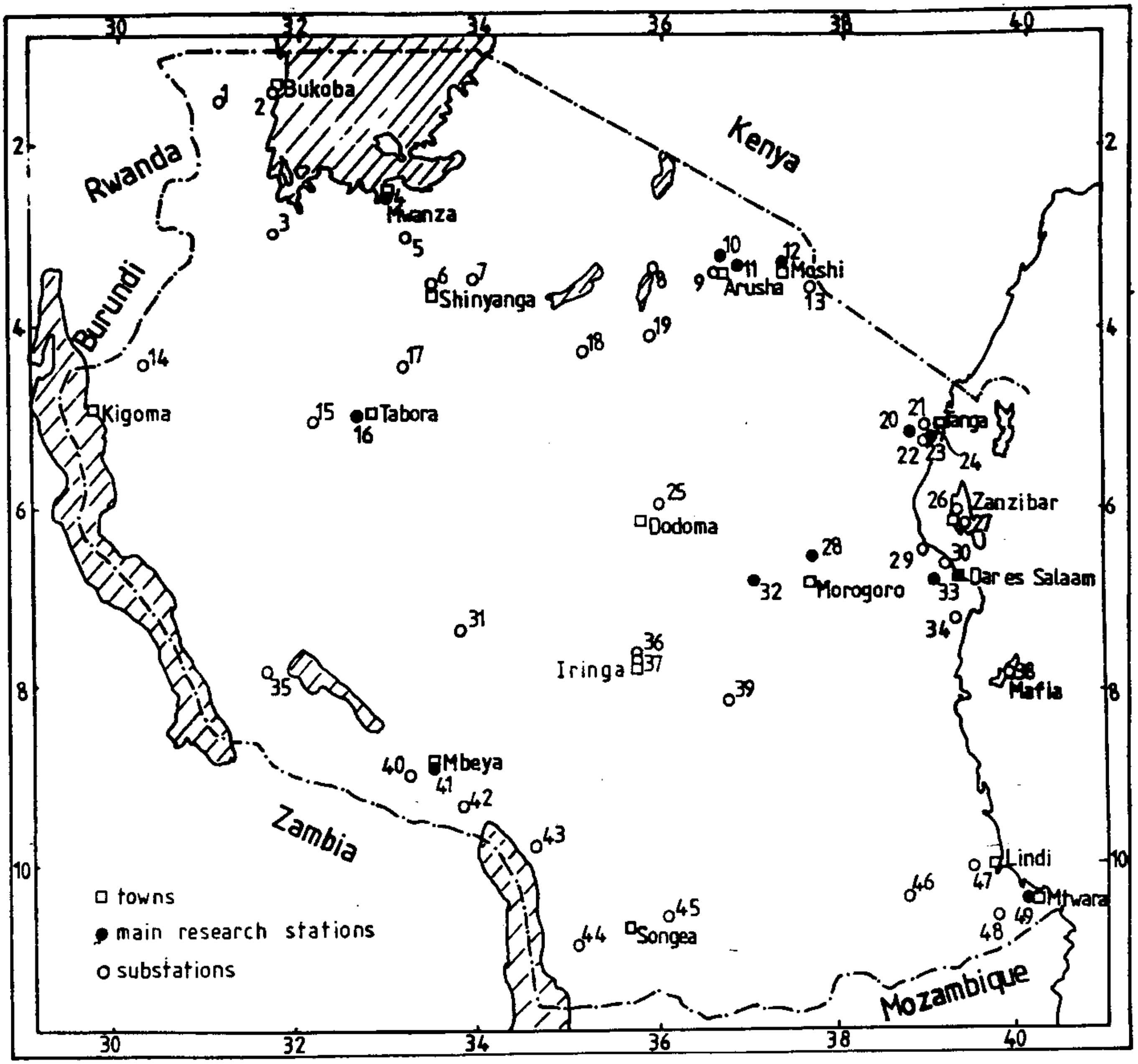
1. Location of Research Stations

Since Tanzania is a large country with variable agro-ecological conditions, the location of research stations is of vital importance. Different crops and cropping patterns can be found in different parts of the country. Currently the research stations are reasonably well placed geographically (Map 2) to deal with production in important ecological zones (Government of Tanzania, 1972). As such, it is easier to organize each station to deal with specific problems for a given area and the results tend to be more adaptable to farmer in that particular environment.

2.Links to International Research Organizations

There is a general consensus that individual countries can benefit from agricultural research conducted at International Institutes, such as the International Rice Research Institute, (IRRI), International Maize and Wheat Research Institute, (CYMMYT), and the International Institute for Tropical Agriculture, (IITA). This consensus is based on the fact that, because of scarce resources, it is impossible to fund research for every commodity in every country. Tanzania has taken advantage of this opportunity, by establishing supportive linkages with appropriate regional and international programs. Some research activites have been geared towards testing and validating the improved technologies developed by international research organizations. For example, Ilonga Research Station has been involved in improving commercial maize varieties "UCA" and Katumani, introduced by CYMMYT. Other examples are work at the Arusha Research Center on wheat

MAP 2: LOCATIONS OF RESEARCH STATIONS IN TANZANIA, 1983



1. Kituntu
2. Maruku
3. Bwanga
4. Ukiriguru
   Mwabagole
5. Mabuki
6. Lubaga
7. Mwamala
8. Mto wa mbu
9. Arusha
10. TPRI
11. Tengeru
12. Lyamungu
    Lambo Estate
13. Miwaleni
14. Kasulu
15. Urambo Seed Farm
16. Tumbi
17. Mwanhala
18. Hanang Complex
19. Magugu
20. Marikitanda
21. Maramba
22. Muheza
    Zigi
    Kizugu
23. Mlingano
24. LBS Tanga
25. Hombolo
26. Selem
27. Bambi
28. Dakawa
29. Chambezi
30. Mpiji
31. Chunya
32. Ilonga
33. Kibaha
34. Mkuranga
35. Nkundi
36. Ismani
37. Iringa
38. Kilombero
39. Ifakara
    TAC site
40. Mbimba
41. Uyole
42. Mitalula
43. Igeri
44. Ndengo
45. Suluti
46. Nachingwea
47. Ng'apa
48. Mtopwa
49. Naliendele

Source: Government of Tanzania, 1983.

varieties introduced from various international wheat research centers, and rice research at Ifakara Station, using materials imported from IRRI (Government of Tanzania, 1983). These collaborative activities indicate great deal of awareness of these international research findings.

3.Generation of Improved Material or Knowledge

Agricultural research in Tanzania has had some success in producing improved material, especially new seeds. Major achievements include the maize research program which has identified two new high-yielding composites (Government of Tanzania, 1972). Ilonga Research Station has also been able to release improved varieties of cowpea (Tumaini and Fahari) and greengram (Nuru) (Government of Tanzania, 1983). Such findings have a potential to contribute to national development objectives through increasing farm incomes, consumer income, nutrition and foreign exchange in the case of cash crops. However, the main question on these findings is whether the farmers are aware of the findings. Secondly, are the new varieties well adapted ? The adaptability and awareness of farmers of new technologies will be discussed in the following chapter.

CHAPTER 3

FARMING SYSTEMS RESEARCH

The discussion on FSR in Tanzania in this chapter is largely based on documents published by the FSR project in Tanzania, and the author's experience. The author of this paper was involved in the early stages of FSR in Tanzania, specifically in the questionnaire design and testing for the verification survey in Kilosa District.

This chapter is divided into five sections. Before proceeding with the specific discussion of Farming Systems Research (FSR) in Tanzania, a brief overview of FSR is provided. Then, the history of FSR in Tanzania is described, followed by a discussion on the need for FSR in Tanzania. The fourth section summarizes the focus of FSR in Tanzania, and the last section discusses the strengths and weaknesses of FSR under Tanzanian conditions.

3.1 Farming Systems Research: An Overview

Shaner *et al*. (1982) defines FSR as an approach to agricultural research and development that views the whole farm as a system and focuses on both, the interdependency between the components under the control of the members of the farm household; and how these components interact with the physical, biological, and socio-economic factors not under the control of the household.

The aim of FSR is to increase the overall efficiency of the farming system. That is, FSR seeks to develop technologies that increase productivity in a way that is useful and acceptable to the farming family, given its goal(s), resources and constraints (Norman, 1980). The main elements of FSR are on emphasis on the needs and constraints of small farmers, the use of an interdisciplinary approach, with a problem-solving perspective, a complementary relationship with commodity research, and close contact with farmers through extension.

The FSR methodology is therefore expected to play a major role in establishing basic research priorities, to guide the generation of appropriate technology for small farmers. Harwood (1979) noted that historically most agricultural research bypassed small farmers with limited resources. FSR explicitly attempts to take into account the failings of previous efforts to develop a strategy that more efficiently focuses research on finding solutions to problems facing the small farmers (Bernsten, 1982). The main concern of some scientists, however, is on the cost effectiveness of FSR, especially given the shortage of manpower and funds in most developing countries (Crawford, 1982; Acker and Sungusia, 1985).

The FSR process is divided into four basic activities: diagnosis, research design, testing and diffusion (Norman, 1980; Collinson, 1980; Gilbert *et al.*, 1980). The selection of the target area or group (sometimes referred to as recommendation domain) is very crucial in FSR (McIntosh et al., 1981). Thus, before the diagnostic stage a target area has to be chosen. A target area will consist of farmers within an agro-climatic zone whose farms are similar and who use similar practices (Shaner et al., 1982; Perrin et al., 1976; Dillon and Anderson, 1983). It is important to define a target area, because it will be very expensive to conduct experiments on each farm (Gilbert et al., 1980). Recommendations developed on the basis of experiments conducted on a sample of farms from a given target area are assumed to be applicable to the entire area. Perrin et al. (1976) emphasize that there are no clear rules in defining target areas. Researchers must base their decision on the objective of their research.

In the Indonesian FSR program, the four criteria used to select target areas are (McIntosh et al., 1981):

1. The designation of critical areas in terms of food shortage regions and governmental priorities.
2. The existence of large areas having similar soils and climate.
3. The feasibility of intensifying cropping patterns and farming system based on prior evidence.
4. The availability of markets and infrastructure.

In Tanzania FSR, target area selection was largely based on agro-climatic conditions. The areas chosen were Kilosa, Dodoma and Moshi Districts. Kilosa is one of the districts in the country with a high potential for agricultural development. The average rainfall per month is about 1034 mm (40.55 inches). The short rains (vuli) usually occur from November to early February (average 431 mm), and the long rains (masika) from mid-February to May (average 608 mm) (Lev, 1985). The soils in this district are relatively fertile and infertility is not a major problem (Matzke, 1985). Dodoma District is relatively dry, the average annual rainfall is about 600 mm (23.6 inches) (Cunard *et al*., 1983). Compared to Kilosa District the soils in Moshi District are relatively infertile. Yet, Moshi District is one of the most intensively cultivated areas in Tanzania. The average annual rainfall is about 758 mm (Bureau of Statistics, 1970).

The main aim of the diagnostic stage is to gather information about farmers' priorities, decision criteria, resource availability, constraints, and possible development opportunities (Dillon and Anderson, 1983; Norman, 1980; Eicher and Baker, 1982). This information can be gathered either by informal exploratory survey and/or formal verification survey (Byerlee and Collinson, 1980). An exploratory survey involves a small multi-disciplinary team travelling through the target area to observe, talk to farmers and record all the relevant information. On the other hand, a formal survey involves the use of a structured questionnaire and follows standard methods of sampling within the target area. In general, formal surveys are more costly and time consuming than informal exploratory surveys (Dillon and Anderson, 1983). The FSR project in Tanzania conducted both the informal and formal surveys. The purpose of the informal survey was to identify problems and constraints to improved farming and higher production within the specified target areas. A multi-disciplinary team composed of an agronomist, extension agents, and several field officers from the crop commodity programs of maize, sorghum and legumes informally interviewed farmers (Cunard et al., 1983). Based on the informal survey, questionnaires were designed for the formal survey. The formal survey aimed at obtaining three kinds of information (Tanzania FSR project, 1984):

1. Information on specific areas of constraints insufficiently examined during the diagnostic stage.
2. Information to verify hypotheses regarding research areas with high potential for on-farm trials and testing.
3. Data on the performance of existing technologies against which performance of introduced technologies can be measured.

Based on CIMMYT's experience, Collinson (1982) advised that it was not necessary to conduct both informal and formal surveys in East Africa. He noted that formal surveys in East Africa had never seriously contradicted the findings of the informal surveys. Dillon and Anderson (1983) however, suggested that verification surveys may be necessary if systems modelling (ie. mathematical programming analysis) is to be used.

The information obtained from the diagnostic phase is then used in the design stage of research. The design stage involves the identification of possible system changes that might be feasible and relevant (Dillon and Anderson, 1983; Shaner et al., 1982; Gilbert et al., 1980). At this stage improved practices must be identified for testing at the farm level (Gilbert et al., 1980). Anderson and Hardaker (1979) suggest that the design stage must also involve ex ante economic appraisal. The FSR team in Tanzania identified the problem of the hungry month as the highest priority problem in Kilosa District. This occurs in February when food is scarce (Cunard et al., 1983). The FSR team identified the introduction of early planted rice and sowing maize in bottom-land as possible solution. Farm trials were therefore designed to test these hypothesis.

If the results of on-farm trials are promising, the technology can be tested on farmers' field. The main objective of this stage is to evaluate the suggested improved technology. Gilbert et al. (1980) identify two parts of the testing stage:

1. Trials at the farm level that use farmer's land and maybe labor, but with the managerial input still provided by the researcher (ie., researcher managed trial).

2. Farmers testing with farm families providing their own land, labor, capital and management (ie., farmer managed trials).

At the testing stage it is important to specify the conditions under which the technology was tested. This information is helpful when the technology is to be applied to similar areas (Gilbert et al., 1980). Dillon and Anderson (1983) argue it is also necessary to involve extension workers directly in the on-farm testing activities so they become fully informed.

The diffusion stage involves the extension of those new technologies which have been tested and shown to be acceptable to farmers (Shaner et al., 1982). In addition the changes that take place within the farming system need to be recorded. Such information is a useful management tool to improve the effectiveness of an on-going project and also are valuable input for the design of new activities (Gilbert et al., 1980).

Despite these neat stages found in most of the FSR literature, in practice different people or organizations have used different variants of these to suit their situation. Bernsten (1985) explained this situation as follows:

> ... The appropriate manner in which systems research is implemented in a particular country will depend on its historical experience, availability of manpower and financial resources, and the cultural milieu in which the effort is undertaken.

The following are some of the examples to illustrate the span of the application of FSR.

Indonesian Cropping Systems Research
(McIntosh, *et al*., 1981; McIntosh, 1982)

In 1972 cropping systems research in farmers' fields was initiated in Indonesia by the Central Research Institute for Agriculture (CRIA), later renamed the Central Research Institute for Food Crops. Five main phases were involved:

1. Site selection and description.

   This was based on information from surveys and secondary data. The sites were described in term of both physical and economic factors. Sites were selected to represent large agro-climatic zones to maximize the potential to extend research to a large area.

2. Biological feasibility and evaluation.

   This phase involved conducting trials in small plots (3 by 5m) which were managed by researchers, and economic farm recording (e.g., income, labor and market price information). The information is then used to evaluate the alternative cropping patterns.

3. Designing and testing of cropping patterns

   In this stage the main factors which were considered in selection of crops to be grown were agronomic adaptability (mainly total rainfall and monthly distribution) and marketability and profit potential. The selected pattern were tested on farmers' fields in 1000 sq meters plots.

4. Pre-production testing

This involved the evaluation of the appropriateness of the technology through multi-locational testing and assessment

of existing infrastructure to support the new technology.

5. Implementation and technology transfer

This involves the transfer of promising technologies to new target areas with similar conditions.

It was demonstrated that at the cropping systems sites throughout the country, there was an increase in cropping intensity, yield, and farmers' income. The research team also identified the lack of supporting services for seeds, fertilizers, pesticides and marketing as the major constraint to adoption of new technology.

Farming Systems Research in Burkina Faso.

(Ohm *et al*., 1985)

The main focus of FSR in Burkina Faso was to identify the principal constraints to increased food production and to identify technologies appropriate to farmers. They first conducted a census in each village which was then the basis for farmer selection. This sample was used in socio-economic surveys to identify production constraints and to understand farmers' decision environment. They then tested the potential of promising technologies. Both farmer managed and researcher managed agronomic trials were conducted.

The team was charged with evaluation of four types of technologies to be tested in five villages of varying agro-ecological environments:

1. Water conservation by tied-ridging to capture water and reduce rainfall runoff and thereby increase the amount of water available to the plants.
2. Amelioration of soil fertility by application of manure and/or chemical fertilizers.
3. Cereal-legume crop associations to reduce production risks and to benefit from the nitrogen fixed by legumes.
4. Testing of new crop varieties.

Results showed that tied-ridges could result in significantly increased grain yield. Some farmers adopted the tied ridge, fertilizer and new variety. The researchers were interested in further studying the adoption patterns of new technologies. Generally, they thought that there was a strong relationship between adoption and farm size.

Production Systems Research in Senegal

(Bernsten, 1985; Bernsten, 1986)

The Senegal Production Systems Research was initiated in 1982. Under the management of the Senegal Agricultural Research Institute (ISRA) and was conducted in three locations, Djibelor, St. Louis, and Kaolack. Two main phases were involved in this case :

1.Diagnostic Survey

In each of the three locations the research began with a rapid census of selected villages. Based on such factors as the organization of labor, use of animal traction, and crops grown, subsystems were identified for each location. At the same time research themes and associated priorities were established.

2.Agronomic, economic and special focus surveys

In each subsystem representative villages were selected whereby detailed surveys and on-farm trials were initiated. In this case on-farm trials were conducted during the time when formal surveys were conducted. The main objective was to identify constraints and collect data to evaluate promising interventions.

The above examples show that it is not necessary to follow a rigid step-wise methodology, but that a flexible approach appropriate for a given country at a given point in time needs to be developed.

3.2 Farming Systems Research in Tanzania

3.2.1 History

The FSR approach was first introduced in Tanzania in 1976, when the International Center for Improvement of

Maize and Wheat (CIMMYT) presented the FSR approach in a proposal to the National Crop Research Planning Committee (Collinson, 1982). Following the approval of the Committee in 1977, FSR demonstrations were instituted at Ilonga Research station in Morogoro and Uyole Research Center in Mbeya. Between 1977 and 1983, when FSR was reintroduced, there was very little progress made in utilizing the FSR approach by the research system in Tanzania. However, in 1980 the Sokoine University of Agriculture began the FSR program in Morogoro. It is interesting to speculate why the FSR procedure demonstrated in the two research stations was not widely adopted by the national agricultural research service in Tanzania. One possible explanation could be the shortage of manpower. Alternatively, it might have been difficult for the already existing research scientists to switch from commodity research to FSR.

In 1983, Tanzania Agricultural Research Organization (TARO) began field operations for the USAID supported Tanzania FSR project (Tanzania FSR Project, 1985). The pilot project is concentrated in the geographical zones served by the Ilonga and Lyamungu research stations. FSR is primarily in progress in three districts - Kilosa, Dodoma and Moshi. Three other districts - Mpwapwa, Arumeru and Morogoro - serve as secondary sites. Both contract expatriate and Tanzanian personnel participate in the FSR program. From the available information it is not clear if there has been any connection between the earlier (1977)

FSR work done by CIMMYT and the new USAID supported FSR project. This could be an example where the same thing is being done by different organizations in the same country without any systematic continuity of efforts.

3.2.2 The need for FSR in Tanzania

Collinson (1980) observed that traditional agricultural research in Eastern Africa has not paid adequate attention to the priorities and economic situation of small farmers. He emphasized that recommendations which are incompatible with the priorities of the small farmers will be unacceptable to them. Dillon and Anderson (1983) noted that the degree to which traditional research approaches fail to address farmers' problems determines the usefulness and need for FSR. Agricultural research in Tanzania has been focused on single crops (Government of Tanzania, 1982) whereas the majority of small farmers grow a mixture of crops. As such, the real problems facing farmers have not been adequately addressed. Collinson (1980), based on his experience in East Africa, suggested that FSR approach can potentially help to produce results which address small farmers' problems. Realizing the deficiency of the traditional research approach, it was recommended in the Tanzania National Agricultural Policy statement (Government of Tanzania, 1982) that agricultural research should adopt a farming systems approach.

One of the factors favoring FSR is that many traditional practices used by small farmers for generations are sound and should be preserved. Farmers' greatest resource is their long experience working on a particular environment (Mbilinyi, 1973). In much conventional research, researchers often have cut themselves off from such valuable knowledge. The farming systems approach has the potential of utilizing the farmers' experience as an integral part of the research process (Gilbert et al., 1980). However, in order for FSR to achieve its potential it is essential that researchers be committed to the approach. They must understand the concepts and principles and be able to make adjustments where necessary.

Another factor favoring the FSR approach is its objectives. The primary objective of FSR is to improve the well-being of farm families by improving productivity of the farming system, through providing farmers with relevant and improved technology (Shaner et al., 1982; Gilbert et al., 1980; CGIAR, 1978). This is consistent with the overall development strategy of Tanzania. Thus, if FSR is successful in achieving its objectives in Tanzania, it will be a great contribution towards the development of the rural society and the country as a whole.

3.2.3 The Focus of FSR in Tanzania

Previous efforts implementing FSR have largely focused on the diagnostic phase (Collinson, 1982), including work in Morogoro and Kilosa District under the CIMMYT project, work in Ufipa District conducted by research scientists from Uyole Agricultural Center, and surveys by the Sokoine University of Agriculture in the early 1980's. The USAID/-TARO FSR project, which started in 1983, focuses on both on-farm and on-station trials. The following summarizes some of the work completed in the three districts, as reported in the third annual report of the Tanzania FSR project (1985).

Kilosa District

The main crops grown in this district are maize, sorghum, beans, cowpeas, cassava and sweet potatoes.
FSR has mainly focused on maize, maize with cowpeas and maize with greengram intercrops. Some trials were also conducted on cotton with maize intercrop. Four research programs were conducted:

1. Short rain (Vuli November-early February) season experiment program

During this season maize, cowpeas and greengram were grown. The main objective of this program was to assist the farmer in developing an effective vuli season production package.

Two kinds of experiments were carried out, a maize variety evaluation and a maize with cowpeas and greengram intercrop. Plots were managed by farmers, but they received recommendations on spacing from researchers.

Kito, an early maturing (90 days) maize variety was compare with local variety (120 days) in the maize variety evaluation experiments. Yield performance was the main decision criterion for this experiment.

The results showed that farmers preferred the Kito (Lev, 1985) because farmers realized that in drier years Kito may have a yield advantage over long season varieties. Farmers were also impressed by the variety's short duration since it allowed them to both harvest the first crop and also plant the long season crop earlier.

The obvious omission in the assessment of these results is an economic analysis. Since Kito yielded about 15 percent less than full season maize varieties, this loss may outweigh the above advantages.

Five treatments were tested in the maize with cowpeas and greengram intercrop. Sole cropped maize, maize with cowpeas planted simultaneously, maize with cowpeas with a two week delay in cowpea planting, maize with greengram planted simultaneously, and maize with greengram with a two week delay in greengram planting.

The results of this experiment were disappointing because all legumes were destroyed by grasshoppers, rats or birds. It appeared though that the greengram was even more susceptible than the cowpeas.

2. Long rain (Masika Late February - May) season experiment program

Crops grown in this season were maize and cowpeas and the objective was to determine the optimum crop density for improved and local maize varieties, and maize intercropped with cowpeas. The plots were planted by researcher but managed by farmers.

The results showed that the improved variety staha out-yielded the local variety. The average per hectare yields for staha was 1.73 tons in the trials. For the local maize (Kipegele) yield was 0.61 tons per hectare.

The crop density aspect of the trials did not provide significant differences in yield. It was also observed that increased density needed a relatively higher level of management.

3. Off-season experiment program

In this program maize (Kito, staha and local variety), and beans were grown. The objective was to determine the possibility of growing crops for 12 months of the year in certain parts of the district.

Three kinds of experiments were conducted maize variety trial under residual moisture, maize with beans intercrop under residual moisture, and beans under residual moisture

The analysis was based on the yield performance of the crops, however, the problem in this season was found to be rats which resulted losses of up to 50-100 percent of grain production and therefore it was not possible to make fair comparisons.

4. On-station experiment program

Crops grown in this program were maize, cowpeas, crotalaria and cotton. Crotalaria is a wild legume and known to fix large amounts of nitrogen in the soil than other legumes. Crotalaria has been considered effective in suppressing weeds and it provides forage for animals. The objectives were to determine the influence of crotalaria on crop production, and to determine the economic advantages of various intercrops.

Four experiments were conducted, 1) a maize with crotalaria intercrop density trial; 2) a maize with crotalaria intercrop, weeding effect; 3) a cotton with maize intercrop yield trial and 4) maize alley cropping with leucaena. These experiments were conducted in collaboration with the commodity research programs at Ilonga Research Station.

The results of these experiments were not completed at the time of reporting.

Dodoma District

The main food crops grown in this district include, millet, sorghum, cowpeas greengram and groundnuts. Cattle keeping is also common in this district. The experiments largely focused on improving soil fertility and crop management. Five experiments were carried out in this District:

1.The use of tied-ridges in cereal production.

In this experiment sorghum and millet were grown on station. Based on the fact that rains tend to be insufficient and unevenly distributed in Dodoma this experiment was designed to investigate the effect of tied-ridges on the grain yield. Tied-ridges were expected to trap water so as to help delay water stress to plants in case of insufficient rains.

At the time of reporting, analysis of this experiment was not complete. However, the following data were expected to be recorded: grain yield, labor time per treatment, farmers' assessment of the treatments, and crop appearance to assess the water stress.

2.The application of Minjingu Rock Phosphate on groundnuts.

This experiment focused on groundnuts. The idea for the trial originated from the observation that there was phosphate deficiency in most of the groundnut growing areas in Dodoma. Thus, it was intended to assess the effect of Minjingu rock phosphate on the yields of groundnuts. These experiments were established by researchers on farmers' fields and the farmers managed the plots subsequently.

The data to be recorded included the yield of groundnuts and the analysis of soil samples to test the phosphate levels.

3.Soil conservation trial.

This was an on-station experiment conducted at Hombolo Research Station. The crops planted were sorghum and millet. The objective was to compare the effect of four conservation tillage methods of planting through a mulch, planting on open ridges, planting on tied ridges and the farmers practice of clearing the soil on crop yield.

At the time of reporting the results of this experiment were not ready.

4.Farm yard manure (FYM) application method.

This was an on-station trial at Hombolo research Station and the crop grown was millet. The objectives were to determine the best method of applying FYM, the optimum level of applying FYM and to relate the yield response to FYM to changes in the chemical and physical properties of the soil.

The analysis was to be based on the grain yield and the chemical and physical properties of the soil.

5.Sorghum, millet with crotalaria intercropped.

This experiment was conducted at Hombolo Research

Station and the crops grown were sorghum and millet intercropped with crotalaria.

The objective was to determine the effectiveness of crotalaria in improving soil fertility, and in controlling weeds.

The analysis was to be based on grain yield and labor time in weeding.

Moshi District

Moshi District is one of the most intensively cultivated areas in Tanzania. The main food crops in this district include maize, beans, and bananas. While coffee is the main cash crop. The experiments in this District were also focused on the improvement of soil fertility.

Two experimental programs were planned for this District, involving on-station and on-farm experiments. The experiments conducted on-station included the testing of various methods of planting crotalaria, crotalaria rotated or intercropped with maize, a maize with beans spatial arrangement trial and a coffee with crotalaria intercrop.

The on-farm experiments were to evaluate the possibility of growing crotalaria under low rainfall conditions. The experiments were not yet designed at the time of reporting.

These are just some of the experiments undertaken by the FSR team. They have largely focused on the priority problems of the respective districts. Generally the main focus has been on food crops.

3.3 Strengths and Weaknesses of FSR in Tanzania

Philosophically, FSR is consistent with the current goal to develop and disseminate appropriate technologies that increase agricultural productivity and to improve the standard of living of small farmers. However, FSR has not yet been established as an efficient way to improve the livelihood of small farmers (Norman, 1980; Crawford, 1982). Some authors argue the approach is expensive and ineffective as the overly optimistic expectations created by the FSR enthusiasts of rapid increases in food production in developing countries have not materialized (Cornelia, 1985). Although it is too early to assess the effectiveness of FSR in Tanzania, this section focuses on some of the strengths and weaknesses of FSR approach, relative to the already mentioned weaknesses and strengths of commodity agricultural research in Tanzania.

3.3.1 Strengths of FSR

FSR in Tanzania addresses some of the general weaknesses of traditional commodity research in Tanzania, including strengthening research-extension linkages, initiating on-farm based research, documenting and disseminating research results and increasing the complementarity between FSR and commodity research.

1.Research-Extension Linkage

Kellogg *et al*. (1985) recognized that one of the reasons the FSR methodology was developed was due to problems caused by the existence of such a gap between extension services and agricultural research, and Collinson (1980) emphasized that FSR procedures offer an excellent device to close the gap between extension and research. It was suggested by Bernsten (1982) that one of the ways to measure the success in strengthening research-extension communication is in the success in staffing programs with research-extension teams.

As was noted in Chapter 2, a gap has existed between agricultural research and extension services in Tanzania. Acker and Sungusia (1985) described the situation at the beginning of the FSR project as follows;

> ...the project was launched with its base of operations solidly grounded in the research organization, with no formal agreement with the extension service as to how joint collaboration on technology development and transfer was to be made operational...

The FSR project was successfully involving a total of eight extension personnel in the FSR team work by 1985, in their respective districts. Therefore, at this stage FSR has served to motivate extension workers and researchers to work together. This being only the first phase of the project it can be anticipated that more extension personnel will be involved in FSR in the long run. In the final analysis this is expected to improve the relevance of the technology developed, which in turn may improve the confidence of the farmers in the extension workers and their advice.

2.Emphasis on farm based research

Ruthenberg (1964) observed that small farmers in Tanzania respond positively to innovations, particularly to new crops and new means of production, when it is demonstrated that these are to their advantage. Sands (1985) suggested that moving research outside the research station boundaries establishes the context for collaboration between the researcher and the farmer.

The FSR project has conducted both on-farm and on-station experiments. In Tanzania, on-farm trials have had two very useful demonstration effects. First, they make farmers aware of the existing new technologies. Second, they identify technologies which are adaptable under farmers' conditions. For example, the verification survey in Kilosa District found that 35 percent of the farmers had grown the improved introduced variety. After the on-farm trials the following year, 44 percent of fields were planted of the improved introduced variety. It was also possible to identify the Kito maize variety, which has a smaller plant structure, as most likely to be adaptable by farmers intercropping maize with other crops, especially legumes (Tanzania FSR Project, 1985).

The on-farm trials also facilitated the collaboration between researchers and farmers. As it was noted in the Third Annual Report (Tanzania FSR Project, 1985) that FSR team in Tanzania has actively involved farmers in the management and evaluation of the introduced innovations through on-farm research. Sands (1985) noted that farmer involvement is important for research to be relevant under their social, economic, and environmental conditions.

3.Documentation and dissemination of research information

The quantity and quality of FSR project documentation has been satisfactory (Tanzania FSR Project, 1985). The FSR project has been able to document all the research work conducted in the respective target areas. The documents available to date include the annual and quarterly reports, reports for various research work done by FSR team and reports by consultants to the FSR project. Such documents are useful to researchers and the Ministry of Agriculture, and will establish a foundation for future FSR work in Tanzania. However, this is not enough. It is useful also to have non-technical documents (Abraham, 1975) which can be incorporated into the extension program and become directly useful to farmers.

4. Complementarity between FSR and commodity research

FSR is a complement to, rather than a substitute for, commodity research programs (Norman, 1980; Shaner et al., 1980; Dillon and Anderson, 1983; Gilbert et al., 1980; Cornelia, 1985). Recognizing this, the FSR project in Tanzania conducted on-station trials in collaboration with the commodity programs. About seven commodity oriented researchers had joint experiments with the FSR team. For example, a soil scientist at Ilonga Research Station was involved in the analysis of the soils in the experimental area in Kilosa District. The results were then used in the design of on-farm and on-station trials. Researchers from national grain legumes program, national cotton program, national maize program and national bean program were also jointly involved with the FSR team in the design and management of various experiments. Thus, FSR in Tanzania significantly stimulated collaboration between FSR and experiment station based commodity programs (Tanzania FSR Project, 1985).

3.3.2 Weaknesses of FSR

Although FSR seem to correct some of the weaknesses of traditional agricultural research, there exist some implementation problems. The ones which can be observed under the Tanzanian condition include a shortage of trained manpower and funding, evaluation and time frame.

1. Shortage of trained manpower and funding

Gilbert *et al*. (1981) noted that the major problem facing FSR is lack of funds and manpower. FSR as implemented in Tanzania has been limited to only three districts in three regions out of twenty-one regions in the country. Originally, a total of six districts were to be involved but finally the effort had to be narrowed down to only three districts. This is due to insufficient funding and manpower (Tanzania FSR Project, 1985).

However, it is anticipated that in the long run there might be more personnel involved in FSR since the FSR project provided for both long-term (MS and PhD) and short-term training for Tanzanians. In co-operation with CIMMYT's regional training office in Nairobi, seminars and workshops were conducted involving both extension workers and researchers. The main focus of the training sessions was to provide an overview and understanding of the FSR process to the participants. This is an important step for the re-orientation of researchers and extension workers in the adoption of the FSR approach. This enables staff to better understand and appreciate the need for FSR approach. The long-term training involved the training of four agricultural economists, two agronomists, a plant breeder, an entomologist, an agricultural engineer and a plant protection specialist.

The problem of limited funding can be partially dealt with by further modification of the procedures employed in data collection and analysis (Collinson 1980). The Tanzania FSR project can also reduce the cost involved by making some changes in the research process. For example, the FSR can make more use of the available information in research stations, and in so doing some of the on-station experiments can be eliminated. Yet, the fact that USAID financial support has been terminated may lead to a serious financial constraint in the near future. As such, the continuation of the FSR project will depend largely on the Tanzania Agricultural Research Organization to find ways of allocating local funds to the project.

2. Evaluation

Although FSR may represent a major step toward more relevant research, it is important at this stage to determine the cost involved (Eicher and Baker, 1981). Some authors argue that because of location specificity, FSR appears to be expensive to execute (Norman, 1980; Harwood, 1979). According to Collinson (1980), the FSR procedures promoted by CIMMYT involved low costs. This was mainly because of the modified procedures followed in the diagnostic phase and analysis of data. To evaluate this argument, estimates of the cost of specific research activities such as surveys, on-farm trials, data analysis etc. should be made. Such information can then be incorporated in the evaluation of the FSR approach and make further modifications where necessary. Norman (1980), suggested that there is a need to find ways which will make results more widely applicable so as to maximize the returns of the research efforts.

3. Time Frame

Many authors of FSR point out that FSR programs require several years before improved technology can be recommended (Gilbert _et al_., 1980; Collinson, 1980;). Collinson (1980) suggested a period of six years. Other scholars (Lev and Campbell, 1985) argue that FSR has too short a time horizon, and that FSR researchers do not fully understand the longer run objectives and constraints of small farmers. The FSR project in Tanzania was planned with a time frame of three years, that is, March, 1983 to September, 1986 (Tanzania FSR Project, 1985). This may not be enough time for the FSR approach to be proven as a better research approach in Tanzania. Secondly, within three years FSR may not be able to provide fully tested technologies appropriate to small farmers. However, the Tanzania Agricultural Research Organization (TARO) is expected to adopt the FSR approach after the external support of the project is terminated.

CHAPTER 4

ANALYTICAL OBJECTIVES AND MODELS

To design experiments which can be analyzed efficiently, researchers must understand the evaluation criteria and analytical procedures to be used. Malcom (1970), showing his dissatisfaction of some types of analysis carried out in East Africa, said "in general the resources used in summarizing and preparing data for analysis have not been employed very efficiently." Crawford (1981) noted that relatively little attention has been paid to data analysis. Weak analysis may pose an obstacles to successful research on farming systems.

In this chapter some of the analytical procedures to be considered in evaluating agricultural research are examined. The chapter is divided into three sections. Section one focuses on the analytical objectives to be considered in agricultural research. Section two discusses some of the analytical models which can be used to assess technologies for small farmers. The last section shows how macro factors can be considered in the analysis by carrying out sensitivity analysis.

4.1 Analytical Objectives

In evaluating the potential of agricultural research results for farmers' adoption, all the technical, social and economic factors that interact with the new technology must be considered. Successful technology design and assessment requires:

1. Establishing research priorities that reflect farmers' most important problems.
2. Evaluating biological potential of the new technology as compared to the traditional technology.
3. Evaluating economic profitability of the new technology as compared to the traditional technology.
4. Consideration of critical policy parameters affecting the new technology (e.g., prices of inputs and outputs, availability of inputs and markets for both inputs and output).

4.1.1 To Establish Research Priorities.

Establishing research priorities is an important first step in agricultural research. These priorities are a useful guideline in both data collection and analysis (Hoque, 1984). It is now generally accepted that research priorities must focus on small farmers' needs (Shaner et al., 1982; Collinson, 1980; Norman, 1980; Winkelmann and Moscardi, 1982). FSR can play a very important role in the setting of agricultural research priorities based on farmers' needs. This is because small farmers are the central figure in the FSR process, particularly at the diagnostic and testing phases (Norman, 1980). For agricultural research priorities to focus on small farmers needs, environmental factors, farmer goals and resources, and institutional factors, must be considered (Bernsten, 1982). The performance of a new technology in a given area depends to a great deal on environmental factors, such as rainfall, temperature, and soil type. The assessment of a new technology must therefore be accompanied by the assessment of the environmental conditions existing during experimentation to determine if they have been representative of the typical conditions. Such analysis will show whether the findings are typical or have occurred under atypical circumstances (Shaner et al., 1982). Given the environmental conditions, priority must be given to those crops or livestock which are compatible with such an environment (Bernsten, 1980).

Environmental compatibility alone is not sufficient ground to base research priorities. Many technologies may be compatible in a given area or farming system. However, the ultimate acceptance of the technology depends on farmers' goals (Harwood, 1979; Bernsten, 1980). One of the major goals of small farmers is to secure food supply for their families (Collinson, 1980). Also important is the small farmers' desire to avoid the risk of losing their food supply (Collinson, 1980; Norman, 1969). Analysis of agricultural research must therefore incorporate aspects of risk. Norman (1969) suggested that researchers must try to minimize, as far as possible the actual standard deviation in the returns of new technologies.

The analysis of new technologies must also take into consideration institutional factors that affect profitability, such as market access, pricing of farm products and inputs, credit facilities etc. (Crawford, 1981). This is because there is a great deal of interdependence between these factors and farm production decisions. Discussion on how to incorporate these factors in the analysis is provided later in this chapter.

4.1.2 Assessing Biological Potential

As has already been mentioned in the preceding chapters the main objective of agricultural research for a long time has been the assessment of technologies on the basis of their biological potential. Biological potential involves the determination of such factors as yield potential, fertilizer response, disease resistance, drought tolerant etc. This information alone is not enough in deriving recommendations for farmers (Perrin et al., 1976) because farmers normally do not make their decisions on which crops or animal products to produce on the basis of yield alone (Collinson, 1980). Together with other information, such as labor data, prices of other inputs and output price, agronomic data can further be used in carrying out economic analysis. On the basis of the economic analysis and farmers' needs, recommendations can then be made (Perrin et al., 1976; Ohm et al., 1985).

4.1.3 Assessing Economic Potential

Economic potential criteria involve the determination of the economic returns to a given technology with respect to scarce resources. Ruthenberg (1968) noted that small farmers were willing to adopt innovations which gave higher returns per additional hour of work. Economic potential also involves determining the availability and utilization of the farmers' scarce resources required to implement the changes associated with the new technology (Shaner et al., 1982). The researcher therefore needs to understand how farmers allocate their scarce land, labor and capital resources between production activities to achieve specified goals (Collinson, 1980; Crawford, 1981). Economic analysis is further discussed in section 4.2 of this chapter.

4.1.4 Assessing Macro Factors

There is a general tendency of FSR to focus on micro-economic issues, while almost forgetting that there is a strong interaction between the farm household and its surrounding social and institutional environment (Crawford, 1981). For example, the FSR team in Tanzania suggested the use of the improved maize variety Kito because it performed relatively better than the local variety (Tanzania FSR Project, 1985). However, farmers may not be able to adopt this new variety because they may not be able to get the seed in time. In contrast, local varieties are readily available to them. Researchers also need to assess the profitability or desirability of technologies under a wider range of input and output prices (Perrin et al., 1976; Dillon, 1979). Thus, assessing the potential of new technologies a broad view of the farming system needs to be considered, so that linkages with market institutions and the effects of input output price relationships are also examined.

4.2 Analytical Models

This section will discuss some of the analytical models which can be applied in assessing the economic potential of technologies. It is suggested that for long term investments such as tied-ridges, the returns need to be discounted for the appropriate time period in order to come out with the present value of the future returns. As this analysis focus on evaluating technologies which do not require long term investment, discounting is not necessary. Also the following analysis assumes that economic analysis is carried out after completing agronomic analysis (statistical analysis).

4.2.1 Partial Budgeting

Several authors suggest using simple models to analyze small farm systems (Anderson and Hardaker, 1979; Crawford, 1981; Zandstra, 1982). One of the most commonly used simple model is partial budgeting. Harsh et al. (1981)

defined partial budget as a process of examining only those costs, income and resource needs that change with a proposed adjustment on the farm. Given a new technology or change, a partial budget analysis tries to answer four questions:

1) What extra costs will be incurred ?

2) What existing cost will be avoided ?

3) What existing income will be lost ?

4) What extra income will be gained ?

A net gain in the partial budget analysis means an improvement in returns by the change compared to the existing returns (Coy, 1982; Harsh et al., 1981). Zandstra et al. (1981) suggested that an alternative offering a net return of 30 percent more then the traditional practice, for more then a year of testing, may be considered for recommendation to farmers. Perrin et al. (1976) and Dillon and Hardaker (1980), suggested a 40 percent higher rate of return. These examples suggest that the researcher based on experience of the area in question may set his/her own acceptable rate of return as a basis of comparison. This decision can be based on the apparent minimum rate of return which will be acceptable to farmers in the area of concern. Dillon and Hardaker (1980) suggest that the researcher must take into consideration both the direct and indirect (opportunity) cost of capital and also make an allowance for risk. In their example, 20 percent is an allowance for risk and another 20 percent is the opportunity cost of capital. Partial budgeting is useful when the introduced technology or change does not have a major influence on the whole farming system, such as the introduction of a new crop variety. Partial budgeting involves the comparing the net returns of the introduced variety with that of the traditional variety as illustrated in Appendix 1-A.

The partial budget is relatively easy to use and does not demand advanced analytical skills (Anderson and Hardaker, 1979; Harsh et al., 1981). This is important, for developing countries where access to advanced computer facilities, necessary for more complex models, is limited.

As was mentioned earlier, recommendation can not be based on net returns alone. To take into consideration resource scarcity, partial budget analysis must be carried one step further. Net benefit need to be expressed as return to the scarce resource (Norman and Palmer-Jones, 1977). The researcher needs to determine which of the resources is most limiting to the farmer and then calculate the returns to this factor. Perrin et al. (1976) described how to take into consideration capital scarcity, by calculating net benefits as returns to investment capital. Ruthenberg (1968) observed that the most limiting factor is labor for small holders. Therefore, he suggests that the most relevant criterion is returns per additional hour of work. Norman (1980) found that in Northern Nigeria a seasonal labor shortage was a major constraint in expanding output, so he based his analysis on both returns per annual man hour and returns per man hour during peak labor use period.

Hoque (1984) also applied the rate of return to labor criterion to assess the potential of different cropping patterns in Asia. Net returns to labor can be calculated as follows:

1. If family labor is most limiting then:

   RFL = GR - VC (excluding cost of family labor)/AFL

2. If hired labor is most limiting then:

   RHL = GR - VC (excluding cost of hired labor)/AHL

3. If labor is limiting during peak period then:

   RPL = GR - VC (excluding cost of labor at peak)/APL

Where: RFL = Returns to family labor

AFL = Amount of family labor

GR = Gross returns

VC = Variable cost

RHL = Returns to hired labor

AHL = Amount of hired labor

RPL = Returns to labor at peak period

APL = Amount of the labor at peak period

The returns to the scarce resources can then be compared for the alternative technologies. In Burkina Faso, returns per hour for the additional labor involved in tied-ridging were compared with the opportunity cost of labor in assessing the economic feasibility of tied-ridging (Ohm et al., 1985). The use of this criterion, however, is questionable for situations where more then one input is applied, as in case of fertilizer trials where both capital and labor are involved. In this case it will be inappropriate to consider returns to labor alone. It would be more appropriate to consider returns to the cost of both labor and fertilizer. That is, consideration must also be given to the amount of capital used in the purchase of the fertilizer.

Partial budgets require data for the amount of the variable inputs (e.g., labor), prices of variable inputs and output, and yield with and without the treatment. The CIMMYT manual (Collinson and Byerlee, 1980) provides some guidelines on how to obtain labor input data. First, data can be obtained by questioning farmers carefully about the labor usually required for an operation per unit area. Secondly, researcher must try to identify periods of the year when family labor is fully occupied and periods of slack labor. The proposed technology must try to minimize the use of labor at periods when labor is fully utilized and utilize more labor during slack periods.

However, Dillon and Hardaker (1980) note that the accuracy of the data obtained by questioning depends on the ability of the respondents to recall the information requested and also on their willingness to reply truthfully. They suggest frequent interviews if information is likely to be forgotten over long recall periods. These interviews can be conducted at each time a particular activity of interest is being performed on the farm e.g., land preparation, planting, weeding and harvesting.

Yield and other agronomic data can be obtained from agronomic trials. In estimating yield researchers need to consider three sources of variability:

1. Site-to-site variability under the same management conditions.
2. Year-to-year variability under the same management conditions.
3. Management level variability on a given site and year.

Perrin _et al_. (1976) provide ways of dealing with these kinds of variability in order to get most representative data. They suggest multi-locational testing of technologies, to evaluate the site-to-site variability. To capture year-to-year variability a multi-period time frame in research is suggested. Finally, management variability can be considered by testing the technology under both farmer and researcher management. A comparison may also be done between farmers with different levels of resources (e.g., amount of land, labor or capital) to evaluate the performance of the technology under different farmers' management levels.

Price of inputs such as seeds and fertilizer can be obtained from retail shops (Perrin _et al_., 1976). More detailed information can be obtained from farm surveys.

Another source of such information is secondary data, such as annual price lists published by the government (the case of Tanzania). These prices need to be adjusted by including transportation costs to get real prices facing farmers.

Price of output can be obtained either from secondary sources or farm surveys. Data generated from farm surveys may reflect seasonal price variation which could be useful in assessing technologies. Bernsten (1982) suggested that data should be collected from the source capable of giving the most accurate answer in a minimum of time.

4.2.2 Marginal Benefit Cost Analysis

Marginal analysis involves calculating marginal benefit cost ratio (MBCR) from estimated net yields, gross field benefits and total variable costs. Net yield is the measured yield per hectare in the field minus harvest and storage losses if any. Gross field benefit is net yield times field price. Total variable cost is the sum of the cost of all variable inputs. Then, net benefit = gross field benefit - total variable cost. The MBCR is calculated by first plotting the net benefits against the variable cost to determine the undominated or superior combinations (Zandstra et al., 1981; Perrin et al., 1976). The MBCR is then calculated from the undominated combinations as follows: incremental net benefit divided by incremental variable cost.

Perrin et al. (1976) define MBCR as the increase in net benefit which can be obtained from a given increment of investment. MBCR is normally expressed in percent. It means for every one additional unit of variable cost, the farmer recovers that one unit plus that percent (Shaner et al., 1982; Perrin et al., 1976) of increased benefits over variable costs. It has been found in some studies that technologies offering a higher net return may have a lower rate of return on additional costs (Zandstra, 1981; Hoque, 1984). The MBCR criterion is most appropriate when testing returns to a single input factor at several input levels such as fertilizer (Perrin et al., 1976; Shaner et al., 1982). Generally, the rate of return (percent) declines as the input level increases. The decision criterion for MBCR is to select that alternative with a MBCR equal to or above a level assumed to equal the rate of return (ie. 30 percent) farmers will require to adopt the technology. However, Hoque (1984) applied the MBCR to compare several alternative improved cropping patterns at higher input levels and low input levels in Asia. The decision criterion used was to select that alternative with the highest MBCR from switching from one alternative or level of input to another. This analysis assumes that the farmers' objective is to increase returns above variable costs. For the case where farmers produce primarily for their own consumption, then this criterion of higher returns above variable costs may not be appropriate. Alternatively, Zandstra *et al*. (1981) suggest determining the increase of food production per unit of cash and labor invested. For example, farmers may produce maize. Due to limited access to market, most of it is not sold but consumed at home. Then, rather then converting the maize into money value, the most appropriate criterion will be the increased amount of food produced per unit of labor or cash invested.

4.2.3 Enterprise Budget

Enterprise budgets are used to assess the profitability of a single enterprise on the farm (Appendix 2-A). Eicher and Baker (1982) identify two main ways in which enterprise budgets has been used. First, to compare the costs and returns of different crop and non-farm enterprises, and secondly, to compare costs and returns in producing the same crop with different techniques.

Spencer and Byerlee (1977), using enterprise budget analysis, found that there was no much difference in income between farm and small-scale industrial household in the rural areas of Sierra Leone. Spencer and Byerlee (1976), based on a detailed farm survey, examined labor use in rice production under improved technologies in Sierra Leon using enterprise budgets. They found that neither the biological chemical technology nor the mechanical technology was profitable as measured by returns to the limiting factor which was labor.

4.2.4 Whole Farm Budget

Partial budget, marginal analysis and enterprise budgeting are inappropriate when the introduction of the new technology forces farmers to reorganize substantial portions of their activities on the farm. Under such circumstances whole farm analysis should be conducted (Shaner et al., 1982; Dillon, 1979). Hoque (1984) defined whole farm analysis as:

> ...a methodology designed to search for optimal solutions through incorporation of farmers objectives, farming systems, and resources to arrive at improved cropping and livestock patterns and management practices for overall farming system performance.

Whole farm analysis requires significantly more information about the farm or farming system then does partial budget, enterprise budget or marginal benefit cost analysis. It requires information on the availability and demand for all resources (e.g., land, labor and capital) needed at different times of the production process (Zandstra et al., 1981). Whole farm analysis may incorporate both on-farm and off-farm activities. It helps to answer three questions (Anderson et al., 1977):

1. What activities to adopt on the farm.
2. What method of production to employ for each activity, and
3. What amount of resource to allocate to each activity.

Whole farm analysis implies an increase in analytical complexity along several lines. It is generally time consuming, and requires a substantial staff for data collection and analysis (Zandstra et al., 1981). It may also require special computer facilities and skills (Crawford, 1981).

Whole farm budgeting is a method used in whole farm analysis where the profitability of all enterprises on the farm is determined (Appendix 2-B). Dillon and Anderson (1980) suggested that whole farm budgets are best prepared in gross margin terms.

Upton and Petu (1964) prepared whole farm budgets in their study in two villages in Ilorin Emirate (Nigeria). They found that multiple cropping had a potential of producing a high gross margin per acre. Upton, (1967) in his study in South-West Nigeria using total margin per farm criteria, found that arable crops accounted for the largest proportion of total margin per farm.

Eicher and Baker, (1982) identified four problems associated with budget analysis:

1. That there is no standard approach in deciding what to include in farm budgets.
2. Problem of measuring and valuing farm inputs and output.
3. Interpretation of budgets constructed from average input/output relationships on surveyed data.
4. That budgets based on cross-sectional data do not take account of changes over time and space.

Due to these problems Eicher and Baker argue that, it has been difficult to interpret and compare the results of different studies.

4.2.5 Linear Programming

Linear programming (LP) has been the most widely used method for whole farm analysis (Anderson and Hardaker, 1981; Crawford, 1981; Zandstra et al., 1981; Anderson et al., 1977). LP is concerned about resource availability and the use of these resources by productive activities on the farm. With this model a mix of efficient activities that use the available resources in an optimal way can be identified (Anderson and Hardaker, 1979; Ohm et al., 1985). LP model has three main components (Harsh et al., 1981):

1. The objective function. A variety of objectives have been specified for small farmers such as maximizing total gross margin (Etuk, 1979) or maximizing profit (Farrington, 1976).
2. Restrictions. These specify the available resources on the farm such as land, labor, and capital. In most studies done in developing countries, a minimum subsistence food requirement has also been included as a constraint (Eicher and Baker, 1982).
3. Activities. The researcher must be able to identify alternative activities from which the model can determine the most profitable ones. These may

include crop production activities, buying of inputs, selling of output and consumption activities.

The most outstanding problem for the use of LP in developing countries is the scarcity of data required for the analysis (Crawford, 1981). Due to this problem, MacArthur (1963) considered the use of LP as unrealistic under small farmers' conditions. However, Low (1974) pointed out that the scarcity of data does not mean that LP cannot make a useful analytical contribution under small farmers conditions in developing countries. Several studies in developing countries applied LP and provided useful findings. Clayton (1961) using secondary data, constructed a LP model to examine farm situations in Kenya and evaluated the impact of reallocating land and labor resources between competing activities. He found that family labor, rather than land, as the major constraint in increasing farm output. Heyer (1972) used input/output data collected from farmers in Kenya to construct a LP model. She also identified labor as the major constraint on small-holder farming. The FSR Unit in Burkina Faso (Ohm et al., 1985) noted that LP can be applied in FSR in two ways:

1. To evaluate technologies and policies after all the field data has been gathered and reliable coefficients calculated.
2. As a research planning device to assess potential

avenues of research before specific data collection begins.

The first application has been used by Etuk (1979). Etuk used farm survey data to evaluate the profitability of new technology in Northern Nigeria. The results of the study showed that new technology induced a significant increase in farm income, resource use, and profitability. However, the amount of labor available for work on the farm in peak months was a critically limiting factor in agricultural production with the new technology.

The second application has been done by Farrington (1976), using survey data collected from two site in Malawi over consecutive seasons. Optimal farm plans were developed for good and poor years using a LP model, which were then compared with observed or actual farm plans. It was found that actual cropping patterns remained similar from one year to the next, although relatively lower income was produced in the poor and good years as compared to the potential best. He concluded that farmers' behavior was consistent with a policy of long-term profit-maximization.

The above few examples, suggest that despite the data problem, LP models - if properly specified - can make a significant contribution to understanding and evaluating peasant farming systems.

4.2.6 Sensitivity analysis

Sensitivity analysis is a technique or procedure to test the stability of results obtained from analysis (Shaner et al., 1982). It may be applied to reevaluate initial results obtained using partial, marginal benefit cost enterprise and whole farm budgets.

Errors in estimating prices or costs of both input and output of a given technology is one of the main sources of instability of research findings. Instability can also be due to seasonal variability (Perrin et al., 1976). Estimates of product and input prices may be inaccurate, because researchers may use guaranteed prices, whereas farmers do not generally receive guaranteed prices. Sensitivity analysis, therefore, is a means of dealing with uncertainty about future prices, yields or resource availability. Thus, the researcher may want to test the technology under different price levels (Perrin et al., 1976; Appendix 1-B; and Appendix 1-C). For the case of yield, it may happen that researchers are optimistic about potential yields, especially when the new technology or variety is proposed and the agronomic information is based mainly on experimental trials. Under such circumstances researchers need to test how sensitive for example, net returns are to lower or higher yields. For the case of resources, researcher may want to test the effect of varying levels of the available resources on net returns and the adaptability of the proposed technology. For example, Etuk (1979) tested the effect of varying family labor and operating capital on farms to evaluate the feasibility of the new technology under different levels of labor and capital.

Depending on the objectives of the research and the availability of data, the researcher has to choose appropriate analytical models.

4.3 Farmer Assessment

Economic models attempt to evaluate the profitability of new technology by building into the model the primary factors believed to affect farmers' adoption decisions. These models ability to predict subsequent adoption potential depends almost totally on the researchers understanding of factors that affect farmers' adoption decisions. Therefore, the results of economic analysis should only be considered as a step towards the determination of farmers' assessment of the technology.

Subsequent to completing these analyses, results should be discussed with the farmers for whom the technology is designed. Their evaluation will serve to confirm or reject the results. In addition, bringing back the results to the farmers for their evaluation will increase the research team's understanding of additional factors farmers take into account in assessing technology. Taking into account these factors into subsequent technology design, testing and analysis will improve the relevance of future technology and increase the ability of economic analysis to predict farmer adoption of new technology.

CHAPTER 5

SUMMARY AND STRATEGIES FOR THE FUTURE FSR

5.1 Summary

As in many developing countries, the main constraints to conducting effective agricultural research in Tanzania include shortage of trained manpower, inadequate funding, lack of policy direction in research, insufficient co-ordination between research bodies, inadequate research-extension linkages emphasis on research station based research as opposed to farm based research, inadequate emphasis on socio-economic research and inadequate documentation and dissemination of research information. Despite all these constraints, Tanzania achieved some success in agricultural research, mainly the development of improved export and food crop varieties and animal breeds.

Farming systems approach seems applicable under Tanzanian conditions. Basic to FSR is an appreciation of the farm as a system (Dillon and Anderson, 1983). The fact that small farmers in Tanzania grow several crops in a given year either in sequence or in combination justifies the need for FSR approach. McIntosh et al. (1981) noted that commodity focused research that ignores the interrelationships among all food crops grown fails to meet farmers' needs. Equally important is the fact that some of the farmers' traditional practices need to be carried over or may need to be researched and/or improved. Thus, the fact that FSR emphasizes farmer involvement in the research process will help to identify such factors so they will be incorporated in the research focus. The economic feasibility of the FSR approach in Tanzania will depend to a large extent on the modification of the approach to meet the financial, manpower and the farming situation in the country in general.

The appropriateness of a new technology is largely affected by the environmental conditions, culture of the people involved, farmers' goals and resources, and existing institutions. Thus, in analyzing the potential or acceptability of new technologies, these factors must be incorporated into the design and analysis of new technologies. Physical environment determines the biological potential of a given technology, the culture of farmers will determine whether the new technology will be accepted by farmers. On the other hand, farmers goals and resources will indicate the feasibility of their adopting a given technology. Institutions (e.g., markets, prices) are usually external to the farm, but they do affect the farm either directly or indirectly.

To test the biological potential of a given technology, agronomic trials need to be designed and implemented. In order to take into account site-to-site yield variability, multi-location testing is required. Whereas year-to-year yield variability can be identified by multi-period testing, and management level variability can be identified by conducting both farmer managed and researcher managed trials.

Agronomic trials must be subjected to socio-economic analysis. Economic data on inputs and output need to be collected for each trial. Partial budget analysis is appropriate for those changes on the farm that have minimal affect on the whole farm system. Marginal benefit cost analysis is usually applied to evaluate multi-factor (level) trials such as fertilizer trials. Enterprise budgets can be employed to test the productivity of a new technology which causes several changes in a single enterprise. Whole farm budgeting can be used to evaluate the impact of a major reorganization of the farm, such as the introduction of a new cropping pattern. Linear programming (LP) is also a very useful analytical tool, used to determine the feasibility of a new farm plan, subject to the farmers' constraints.

Sensitivity analysis is carried out to evaluate alternative solutions under different levels of input and output prices and/or different quantities of inputs or outputs. Sensitivity analysis shows the stability of research findings under different conditions.

Analytical models need to be specified before the questionnaire for the survey and the trials are designed. This will insure that only the data required to perform the intended analysis is collected (Bernsten, 1985).

It is important to emphasize here that in assessing the value of new technology, the criterion of maximum profitability should not be the only one used. Consideration should also be given to farmers' goals, their attitude to risk, and the adaptability of the new technology, under the farmers conditions. It is equally important to take into consideration the institutional factors (e.g., markets, prices, credit etc.) which may directly or indirectly affect the adoption of the new technology.

Finally, economic analysis must be supplemented by farmer assessment of economic analysis results. Taking the results to farmers to confirm or reject the analysis will strengthen our confidence that the technology will be adopted by the farmers and identify factors excluded from the analysis that serve as constraints to farmer adoption.

5.2 Strategies for the Future of FSR in Tanzania

The future of FSR in Tanzania depend to a great deal on modifying of the process to suit the social environmental and economic conditions of the country. These modifications can be based on three main sources of information. First, the results from the ongoing FSR in Tanzania. Secondly, experience in other East African or other countries with FSR programs. Lastly, available literature on agricultural research in general and specifically on FSR.

Upon returning to Tanzania, this researcher will assist to strengthen the FSR program in the following ways:

1. Seminar on FSR.

   Present a seminar to present the ideas reviewed in this paper to researchers and extension workers. This will be useful in demonstrating the importance of world FSR literature in providing methodological ideas to strengthen the research program.

2. Review of research findings in research stations.

   Conduct a review to identify useful information necessary in the planning of future FSR activities. With limited funding and manpower there is a need to make better use of the available information within the country.

3. Non-technical documents.

   Conduct a review of on-farm research results and to prepare non-technical documents, preferably in Kiswahili, which farmers can read or which can be used by extension workers for reference. This will help to familiarize both farmers and extension workers to research findings. These documents should be reviewed with extension staff and farmers before they are finalized to provide an opportunity for them to give their opinion as regard to the findings.

4. Economic analysis of trials.

   Provide training in the conduct of economic analysis appropriate to identify those technologies which are consistent with the farmers' economic conditions. This will require training of FSR team members in critical issues involved in economic analysis such as the kind of data to collect, how to collect the data, and kind of analytical tools used to evaluate the trials.

5. Annual conferences.

Promote idea of having annual conferences at the end of the crop year where FSR team members, commodity researchers and extension workers meet will be useful in improving the relevancy of research findings. Such a conference will provide the opportunity for staff to exchange ideas on research findings, farmers problems and possible ways of solving them. Based on this exchange of ideas, the next years trials and socio-economic research could be planned.

APPENDIX 1-A

PARTIAL BUDGET ANALYSIS: MAIZE VARIETY SPACING TRIAL

A maize density trial was initiated in Kilosa District during the long rain (masika) season of 1985 because it was observed that farmers planted maize at a wider spacing then the recommended spacing (Mwanjali, 1985). The objective was to find out the effect of spacing and density on the grain yields of two maize varieties, staha (improved variety) and kipengele (local variety).

Table 1A illustrates partial budget analysis, constructed using data obtained from on-farm trials conducted at Mamoyo Village during the long rain season of 1985. The example compares two spacings (90 by 90cm. and 90 by 50cm), using the same variety, staha. It was assumed in the analysis that the 90 by 50cm spacing uses double the amount of resources as the 90 by 50cm spacing. The results show that there is little difference in returns between the two varieties. An extra loss of TSh. 9 is incurred for growing one hectare of maize at 90 by 50cm as compared to the 90 by 90cm. However, in terms of returns per labor day (labor assumed to be most limiting factor), 90 by 90cm spacing showed a higher rate of return (Tsh. 81.42)[a] then 90 by 50cm spacing (Tsh. 40.66).

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[a]. Exchange rate in 1985, 1 US $ = about 17 TSh.

TABLE 1A. PARTIAL BUDGET ANALYSIS FOR MAIZE SPACING TRIAL IN KILOSA DISTRICT TANZANIA, 1985

Change under review: Comparing the performance of Staha maize variety under two densities, 90 by 90 cm. and 90 by 50 cm.

Losses[b]		Gains [c]	
Extra costs:		Costs saved:	
Seed 25 Kg/ha @ - Tsh 12.96	648	Seed 25 Kg/ha @ - TSh. 12.96	324
Revenue Foregone:		Extra Revenue:	
Gross Return	7245	Gross Return	7560
Total losses	7893	Total gains	7884

Extra loss = 7893 - 7884 = TSh. 9.

Other considerations

Extra labor required for growing one hectare at 90 by 50 cm:Planting 10 mandays; weeding 25 mandays; and harvesting shelling and transportation, 50 mandays.

Yield: 90 by 50 cm, 1440 Kg/ha; 90 by 90 cm, 1380 cm

Returns to labor	90 by 90cm	90 by 50cm
Gross Returns /total labor	81.42	40.66

Source: Adopted from Dillon and Hardaker, 1980.

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b. Extra cost in growing one hectare at 90 by 50cm, plus revenue foregone in growing one hectare at 90 by 90cm.

c. Costs saved for not growing one hectare at 90 by 90cm, plus revenue for growing one hectare at 90 by 50cm.

APPENDIX 1-B

SENSITIVITY ANALYSIS: PRICE OF SEEDS

Table 1B shows a partial budget analysis like in Table 1A, with the price of seeds changed from Tsh. 12.96 to Tsh. 15. It is assumed that due to marketing costs farmers may pay a higher price for the seeds (TSh. 15) than the guaranteed price (TSh. 12.96). This is an example of a sensitivity analysis whereby input price is changed.

The results show that, with an increase in the price of seed (from TSh. 12.96 to TSh. 15) extra loss incurred for growing one hectare of maize at 90 by 50cm also increases from TSh. 9 to TSh. 60. That is the loss is higher at higher input price.

In terms of returns to labor the 90 by 90cm spacing gives an even higher returns to labor (TSh. 80.82) than the 90 by 50cm spacing.

TABLE 1B. SENSITIVITY ANALYSIS OF A PARTIAL BUDGET FOR MAIZE SPACING TRIAL IN KILOSA DISTRICT TANZANIA, 1985.

Change under review: Comparing the performance of Staha maize variety under two densities, 90 by 90cm and 90 by 50cm, with a change of price of seed from TSh. 12.96 per Kg. to TSh. 15 per Kg.

Losses		Gains	
Extra costs:		Costs saved:	
Seed 25 Kg/ha @ - Tsh 15	750	Seed 25 Kg/ha @ - TSh. 15	375
Revenue Foregone:		Extra Revenue:	
Gross Return	7245	Gross Return	7560
Total losses	7995	Total gains	7935

Extra loss = 7995 - 7935 = TSh. 60

Other considerations: Same as for Table 1A.

Returns to labor	90 by 90cm	90 by 50cm
Net Returns /total labor	80.82	40.06

Source: Adopted from Dillon and Hardaker, 1980.

APPENDIX 1-C

SENSITIVITY ANALYSIS: PRICE OF MAIZE

Table 1C show a partial budget analysis like in Table 1A. The price of maize is changed from Tsh. 5.25, which is the guaranteed price offered by the National Milling Cooperation (NMC), to Tsh. 7.50 - the open market price in 1985/86. This is an example of sensitivity analysis where the price of the output is changed.

Results show that with the high open market price of maize (TSh. 7.50), an extra profit of TSh. 126 is realized from growing one hectare of maize at a 90 by 50cm spacing when compared with a 90 by 90cm spacing.

The returns to labor however, is still higher for the 90 by 90cm spacing (TSh. 117.95) than the 90 by 50cm spacing (TSh. 59.72).

TABLE 1C. SENSITIVITY ANALYSIS OF A PARTIAL BUDGET FOR MAIZE SPACING TRIAL IN KILOSA DISTRICT TANZANIA, 1985.

Change under review: Comparing the performance of Staha maize variety under two densities, 90 by 90cm and 90 by 50cm. With a change in the price of maize output from TSh. 5.25 to TSh. 7.50.

Losses		Gains	
Extra costs:		Costs saved:	
Seed 25 Kg/ha @ - Tsh 12.96	648	Seed 25 Kg/ha @ - TSh. 12.96	324
Revenue Foregone:		Extra Revenue:	
Gross Return	10350	Gross Return	10800
Total losses	10998	Total gains	11124

Extra profit = 11124 - 10998 = TSh. 126.

Other considerations: Same as Table 1A.

Returns to labor	90 by 90cm	90 by 50cm
Net Returns /total labor	117.95	59.72

Source: Adopted from Dillon and Hardaker, 1980.

APPENDIX 2-A

INDONESIA: RICE ENTERPRISE BUDGET

Table 2A is an example of an enterprise budget for a rice farm in Indonesia. The data used in this analysis was collected as a part of the project, The Consequenses of Small Farm Mechanizastion, funded by USAID. In this analysis the profitability of a single enterprise (i.e, rice from a particular farm) is determined. The results show that the gross margin is Rupiah 263500.

TABLE 2A. RICE ENTERPRISE BUDGET (RUPIAH/HA), INDONESIA, 1981-1982

Income:	
Rice Cash Sales [d]	391300
Total Gross Income	391300
Expenses:	
Material Inputs:	
Planting Material	900
Fertilizer	7800
Materials	3400
Chemicals	600
Other	700
Labor:	
Temporary Labor	114400
Total Expenses	127800
Gross Margin	263500

Source: Adopted from Harsh *et al*., 1981

[d]. Yield 4852 Kg/ha @ Rupiah 81/Kg. Exchange rate 1 US $ = Rupiah 1,000.

APPENDIX 2-B

INDONESIA: COMPLETE FARM BUDGET

Using the same source of data as in Appendix 1-A, Table 2B has been constructed to show a complete farm budget for a particular farm. In this case all the enterprises (rice farm, renting out land and tractor and off-farm employment) are included in the analysis. The results show that the profitability of all these enterprises is Rupiah 2,675,059.

TABLE 2B. COMPLETE FARM BUDGET (Rupiah), INDONESIA

	Rice	Tractor Rental	Land Rental	Off-farm Employment	Total
Income:					
crop Sale	2516059	0	0	0	2516059
Rent out tractor [e]	0	147000	0	0	147100
Rent out land [f]	0	0	80000	0	80000
off-farm employment [g]	0	0	0	110000	110000
Gross Income	2516059	147000	80000	110000	2853059
Cash expenses:					
Planting Material	800				800
Fertilizer	7800				7800
Materials	3400				3400
Chemicals	600				600
Other	700				700
Fuel - Lub.	0	16400			16400
Services	0	9300			9300
Temporary Labor	114400	24500			138900
Total Expenses	127800	50200			178000
Net Farm Income					2675059

Source: Adopted from Harsh *et al.*, 1981

[e]. 7 hectares @ Rupiah 21000/ha.

[f]. 0.7 hectare @ Rupiah 112676/ha.

[g]. 100 hours @ Rupiah 1100/hour.

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