AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

ECONOMIC ANALYSIS OF ON-FARM AGRONOMIC DATA USING A MICROCOMPUTER: APPLICATIONS TO THE ADAPTIVE RESEARCH PROGRAM IN MALAWI

A PLAN B PAPER

BY

BENSON SAMUEL PHIRI

Submitted to Michigan State University
in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE

MICHIGAN STATE UNIVERSITY
June 1986

MICHIGAN STATE UNIVERSITY
AG. ECON. MICROS DEPT
RECEIVED

JUN 19 1986

REFERENCE ROOM

ACKNOWLEDGMENTS

I wish to thank the members of my committee for their guidance: Drs. Richard Bernsten, Henry Foth and Robert Stevens. Dr. Bernsten, my major professor and advisor, was particularly helpful during my stay.

Funding for my studies was provided by the USAID-University of Florida administered project.

My thanks are also due to Ali and Emman Kamel for typing the first draft.

Finally, a lot of thanks go to Phelire, my wife.

TABLE OF CONTENTS

		Page
List of Tables		i - ii
Chapter I - Importance of Economic Analysis		
1.1	The Problem	1-3
1.2	Background	3-5
1.3	Approach	5-6
1.4	Objective of the Study	6-7
1.5	Presentation	7
1.6	Data Sources	7
Chapter II - Evolution of Farming Systems/Adaptive Research		
2.1	Agriculture in Malawi	8-12
2.2	The Research System Before Reorganization	12-14
2.3	Farming Systems Research	14-19
2.4	Adaptive Research Teams	19-24
2.5	Functions and Objectives of ARTs	24-27
2.6	Other Issues Relating to Adaptive Research Teams	27-31
Chapter III - Issues in Implementing Farming Systems Research		
3.1	Communicating Project Objectives	32-34
3.2	Farmer Involvement	34
3.3	Understanding the System	34-35
3.4	Commodity Program-FSR Dialogue	36
3.5	The Four Stages of FSR	36
3.5.1	Descriptive and Diagnostic Stage	37-38
3.5.2	Design Stage	38-40
3.5.3	Testing Stage	43
3.5.4	Extension Stage	43
Chapter IV - Economic Models for Evaluating On-Farm Data		
4.1	Economic Models	44-45
4.1.1	Simple Benefit Cost Analysis	45-46
4.1.2	Marginal Benefit Cost Analysis	46-50
4.1.3	Production Function Analysis	51-55
4.1.4	Feasibility Programming Models	55-60
4.1.5	Variability Over Time and Space	60-63

4.2 Illustrative Analysis using Selected Economic Models
4.2.1 Data Sources 63
4.2.2 Analytical Tools 63
4.2.3 The Illustrative Analysis 64
4.2.3.1 Variety x Fertilizer Trial 64-78
4.2.3.2 Fertilizer Traial 79-93

Chapter V - Summary and Conclusions 94-96

Appendix I: The PC-CALC Spreadsheet 97-96

Appendix II: The SUPERCALC spreadsheet 99-100

Bibliography 101-103

List of Tables

		Page
Table 2.1	- Land Area, Population and Density by Region and District, 1966 and 1977	9
Table 2.2	- Hectarage by Cultivation and by Region, 1968 and 1969	10
Table 2.3	- Principal Crops: Hectarage Under Cultivation on Customary Land by Region, 1968-1969	11
Map 1.0	Agricultural Research Stations in Malawi	13
Table 4.1	- Maize Yields on On-Farm Farmer-Managed Trial (First Village)	65
Table 4.2	- Analysis of Variance Results (First Village)	66
Table 4.3	- Simple Benefit Cost Analysis of Two Levels of Fertilizer (First Village)	68
Table 4.4	- Sensitivity Analysis Using 1983-84 Maize Price (First Village)	71
Table 4.5	- Sensitivity Analysis Using 1983-84 Maize and Fertilizer Prices (First Village)	72
Table 4.6	- Sensitivity Analysis Using a Hypothetical Maize Price (Second Village)	73
Table 4.7	- Simple Benefit Cost Analysis of Two Levels of Fertilizer (Second Village)	75
Table 4.8	- Sensitivity Analysis Using 1983-84 Maize Price (Second Village)	76
Table 4.9	- Sensitivity Analysis Using 1983-84 Maize and Fertilizer Prices (Second Village)	77
Table 4.10	- Sensitivity Analysis Using a Hypothetical Maize Price (Second Village)	78
Table 4.11a	- Local Maize Fertilizer Trial	80

List of Tables Page

Table 4.11b- Analysis of Variance Table 81

Table 4.12 - Economic Analysis of a Fertilizer Trial 84

Table 4.13 - Economic Analysis of a Fertilizer Trial 86

Table 4.14 - Economic Analysis of a Fertilizer Trial 88

Table 4.15 - Economic Analysis of a Fertilizer Trial 90

Table 4.16 - Economic Analysis of a Fertilizer Trial 92

ECONOMIC ANALYSIS OF ON-FARM AGRONOMIC DATA USING A MICROCOMPUTER: APPLICATIONS TO THE ADAPTIVE RESEARCH PROGRAM IN MALAWI

by

Benson Phiri

ABSTRACT

The Department of Agricultural Research (DAR) in Malawi has made a modest contribution to small farmers in supplying them with recommendations they can adopt. This was largely due to the biological emphasis of the department.

In order to introduce social scientists and following in recognition of the poor adoption of recommended technology, Farming System Research (FSR) was introduced in 1979, that has now changed to Adaptive Research. This also followed a major reorganization of the department into Commodity and Adaptive Research Teams.

Biological scientists rely on analysis of variance in evaluating alternative technologies and while it is useful in determining the significant differences among treatment means, it is not sufficient for making recommendations to farmers. Building on statistical analysis, economic analysis evalutes alternatives in terms of their profitability attractiveness. Economic models that

can be used are discussed and simple benefit cost and marginal benefit cost analyses have been demonstrated in this paper. The results indicate the necessity of economic analysis in making recommendations to farmers and how guidance to policy makers can be had from sensitivity analysis.

CHAPTER I

IMPORTANCE OF ECONOMIC ANALYSIS

1.1 The Problem

Smallholder farmers constitute the bulk of the world's cultivators. They operate in areas where population pressure is high, have access to minimal resources, exist at a low standard of living and are subsistence production-oriented with minimal access to services, including agricultural services. Consequently, to merely subsist these smallholders must use their meager resources efficiently.

While Malawi has enjoyed considerable surplus food agricultural production over the last five years, small farmers have not adopted innovations as much as hoped for by planners (ISNAR, 1982):

> "Malawi has achieved a qualified success in its efforts and is one of the few African countries to achieve positive rates of growth in food and crop production. Yet, the success is qualified because smallholder yields remain low and smallholders have not adopted technological innovations as rapidly as many planners and development experts had anticipated." (Hansen et al. 1982, p. 1).

Farrington (1975) attributes this to the focus of the country's agricultural research:

"the difficulties of applying the results of

> such experimental work to smallholder farming are manifold....and a situation is frequently encountered in which, the results of research efforts, although of apparent technical merit, are found to be unacceptable to the smallholder and unworkable in practice." (Farrington, 1975, p. 5).

He suggests orienting research so that all relevant facts of the farmers' situation are taken into consideration.

Agricultural research in Malawi, until recently, failed to address the majority of the critical needs and priorities of the smallholder community, due to the Department of Agriculture Research's (DAR) orientation to higher resource producers (Nyirenda, 1984). The Research Department's trials were largely on-station, there was little input from farmers. Thus, the trials were no different from those on the stations (ISNAR, 1982). Data analysis failed to take into account economic factors in deriving recommendations. Hence, they were viewed as inappropriate by small farmers. Poor adoption of recommendations and external recognition of the need for reorganization of the Department led to the establishment of Farming Systems Research (FSR) (Hansen, 1981). This approach, recently renamed Adaptive Research, has made partners of the farmers and extension peronnel in the technology generation process.

This paper will explore principles in economic analysis applicable in typical farming systems research projects that must be incorporated into technology assesment if appropriate technology is to be developed.

1.2 Background

Biological scientists performing station research rely greatly on statistical analysis. While useful in determining the existence of significant difference between treatment means, nevertheless, it is not adequate in making recommendations likely to be adopted by farmers (Perrin et al. 1976).

Heady and Dillon wrote:

> "Frequently, the experimental design and statistical procedures used have only allowed indication of whether mathematically significant differences exist between the yield or output level of two or three discrete treatments or input levels...Here the goal of research often has been to answer the question: Does the material or resource, used at any level whatsoever, give a response? (Heady and Dillon, 1960, p. 2).

In contrast to statistical analysis, budget analysis can be used to evaluate the most profitable of several alternative technologies. Production function analysis applies economic principles to determine the profit maximizing level of input application and output level or the most profitable level of inputs for specified output, other things beings constant. Thus, knowledge of

appropriate relationships and economic principles lead to more practical recommendations and inferences.

In Malawi, economic principles have not been used to make recommendations because:

1) Maximum output was used as the criteria for selecting recommendations for farmers, requiring input levels seldom identical to the most profitable levels of output;

2) the statistical methods employed to guide research design were based on biological procedures which generated discrete data for point estimates; and

3) many physical biological scientists were not acquainted with production function concepts and economic principles defining profit maximization or cost minimization. Therefore, economic concepts and principles have not been incorporated into planning experimental trials and analysis.

Economic analysis, although necessary, is not sufficient. In some cases, after thorough economic analysis, technologies are rejected by farmers. This reveals a need for more rigorous analysis for trial development and policy guidance to better reflect the complexity of the situation. (Harrington, 1980).

Harrington (1980) argues that economic analysis alone does not address the complex issue of making

recommendations. He put forward "farmer assessment", whereby farmers' experiences with technology are used to guide on-going research and policy issues bearing directly on the adoptability of that technology. Farmer assessment entails the use of qualitative information. (Harrington, 1980).

Together, economic analysis and "farmer assessment" provide the socioeconomic information needed to arrive at stable and representative recommendations. This approach is now being implemented through adaptive research teams recently established in the DAR in Malawi. This objective justifies the allocation of additional resources to generate new knowledge leading to the development of promising technology to meet farmers' needs.

More resources must be set aside to collect data needed to develop recommendations which consider non-biological facets considered important by smallholder farmers (i. e. cultural and socioeconomical aspects).

1.3 Approach

To develop recommendations, economic analysis of agronomic data-after thorough statistical analysis-must be made.

Several models may be used. These models are generally divided into two broad categories: those which

address the economic profitability of agronomic results and those dealing with whole system feasibility. The first includes budget analysis (partial, complete and marginal benefit-cost), production function analysis and simple risk analysis.

Whole system feasibility models are particularly needed in farming systems research where the farm is taken as a holistic entity and the interdependence between the system's components is considered. Some models applied to the whole system are simplified and linear programming.

This exercise focuses on budgeting techniques using spreadsheet programs for some of the analysis. Spreadsheet programs are only tools which speed up data analysis. When changes are made to one or several data values, the final solution is recalculated rapidly. These programs are especially handy with "WHAT IF" questions (Sonka, 1983). Solutions to such analysis provide feedback to policymakers when testing the sensitivity of changes in prices and other parameters on economic returns.

1.4 Objective of the Study

The objectives of this study are to: 1) review FSR/Adaptive Research in Malawi and point out the need

for socio-economic analysis, 2) describe several trial models appropriate for the analysis of agronomic data, and 3) illustrate and compare selected economic models for evaluating profitability.

1.5 Presentation

To give a clearer perspective, Chapter 2 reviews the evolution of farming systems research with emphasis on what has actually happened in Malawi. In Chapter 3, issues related to methodologies in socioeconomic analysis are discussed. Chapter 4 reviews economic models for evaluating on-farm trials and applies some models to actual data. Analysis of variance is also performed and the results are interpreted. Chapter 5 provides a summary of the study and draws conclusions.

1.6 Data Sources

The data comes from agronomic experiments conducted by the FSR section and adaptive research teams involving agronomists, socioeconomists, extension agents and farmers in Malawi. In addition, the author participated in the FSR project and includes observations based on his experiences.

CHAPTER II

EVOLUTION OF FARMING SYSTEMS/ADAPTIVE RESEARCH

2.1. Agriculture in Malawi

Approximately six million people live in Malawi. Over 90 percent works in rural areas as smallholder farmers (Malawi Government National Statistical Office, 1981). "Some 85 percent of Malawi's 6.3 million people are directly involved in agricultural production, and many others derive their livelihood from service to agriculture" (ISNAR, 1982, p. 3). Pressure on land is increasing so rapidly that in some areas additional land for cultivation is unavailable. Population densities in Northern, Central and Southern regions in 1966 were 43, 42, and 65 per square kilometer. In 1977 these figures were 59, 60, and 87, respectively (Table 2.1).

Maize is the preferred staple for nearly the entire country and is grown by the majority smallholder farmers. Over half of cultivated land is allocated to maize production (Table 2.2). Additional important crops grown are groundnuts, pulses, cassava, millet and sorghum, potatoes, rice, cotton and tobacco (Table 2.3). These crops are grown by small scale farmers in varying intensities throughout the country. There is also some tenant

Table 2.1. LAND AREA, POPULATION AND DENSITY BY REGION AND DISTRICT, 1966 and 1977

Area	1966			1977		
	Population	Land Area (Sq.Km) (1)	Population Density(2)	Population	Land Area (Sq.Km) (1)	Population Density(2)
Malawi	4,039,583	94,079	43	5,547,460	94,276	59
Northern Region	497,491	26,874	19	648,953	26,931	24
Chitipa	59,521	4,281	14	72,316	3,504	17
Karonga	77,687	3,346	23	106,923	2,956	32
Nkhata Bay	83,911	4,082	21	105,303	4,088	26
Rumphi	46,636	4,758	10	52,450	5,952	11
Mzimba	229,736	10,407	22	301,361	10,430	29
Central Region	1,474,952	35,519	42	2,143,716	35,592	60
Kasungu	97,472	7,866	12	194,436	7,878	25
Nkhota-Kota	62,918	4,250	15	94,370	4,259	22
Ntchisi	66,762	1,653	40	87,437	1,655	53
Dowa	182,000	3,237	56	247,503	3,041	81
Salima	86,552	1,986	44	132,276	2,196	60
Lilongwe	408,524	6,146	67	704,117	6,159	114
Mchinji	85,324	3,349	26	158,333	3,356	47
Dedza	230,715	3,616	64	298,190	3,624	82
Ntcheu	164,685	3,416	48	226,454	3,424	66
Southern Region	2,067,140	31,686	65	2,754,891	31,753	87
Mangochi	232,692	6,260	37	302,341	6,272	48
Machinga	226,506	5,952	38	341,836	5,964	57
Zomba	232,391	2,575	90	352,334	2,580	137
Chiradzulu	102,197	764	134	176,184	767	230
Blantyre	237,289	1,885	126	405,062	2,012	201
Mwanza	41,981	2,290	18	70,405	2,295	31
Thyolo	256,605	1,738	148	322,000	1,715	188
Mulanje	398,881	3,442	116	477,546	3,450	138
Chikwawa	142,364	4,835	30	194,425	4,755	41
Nsanje	101,234	1,945	52	105,758	1,942	54

(1) The land areas for certain districts for 1977 are slightly larger than those of 1966 due to technical improvement in measurement and changes in district boundaries within Malawi.

(2) Number of persons per sq. Kilometre.

SOURCE: Population Census, 1977.

Table 2.2. HECTARAGE BY CULTIVATION AND BY REGION, 1968/69, Malawi.

Region	Land Hectarage	Hectarage Possible For Cultivation		Hectarage Under Cultivation		Hectarage Under Maize	
	('000)	('000)	%(1)	('000)	%(2)	('000)	%(3)
Malawi	9,408	5,307	56	1,361	26	1,068	78
Northern Region	2,687	1,236	46	167	13	110	66
Central Region	3,552	2,249	63	609	27	463	76
Southern Region	3,169	1,822	57	586	32	495	84

(1) Hectarage possible for cultivation expressed as a percentage of total land hectarage.

(2) Hectarage under cultivation expressed as a percentage of hectarage possible for cultivation.

(3) Hectarage under maize expressed as a percentage of hectarage under cultivation.

SOURCES: Total land hectarage from the Malawi 1966 Population Census, Final Report. Hectarage possible for cultivation from estimates prepared by the Department of Agriculture, 1965. Hectarage under cultivation and hectarage under maize from "National Sample Survey of Agriculture, 1968/69".

Table 2.3. PRINCIPAL CROPS: HECTARAGE UNDER CULTIVATION ON CUSTOMARY LAND BY REGION, 1968/69, Malawi

Thousand hectares

Type of Crop	Malawi	Northern Region	Central Region	Southern Region
Total Cultivated Hectarage	1,361.5	166.9	609.1	585.5
Maize	1,068.1	110.2	463.2	494.7
Groundnuts	449.3	35.8	216.4	197.1
Pulses	841.2	71.7	352.8	416.7
Cassava	298.6	37.3	89.5	171.8
Millet and Sorghum	496.2	29.9	177.1	289.2
Potatoes	180.5	8.0	93.9	78.6
Rice	48.3	7.6	1.9	38.8
Cotton	36.8	0.5	4.9	31.4
Tobacco	34.7	0.7	28.4	5.6

NOTE: Hectarage under mixed stand are included for each crop in the mixture but only once in the totals. Total also include hectarages under crops not listed above. All figures are subject to sampling error.

SOURCE: National Sample Survey of Agriculture 1968/69.

farming-mainly on tobacco estates. Livestock include dual purpose cattle, goats, pigs, poultry and sheep.

Malawi has a comparative advantage in agriculture relative to other African nations.

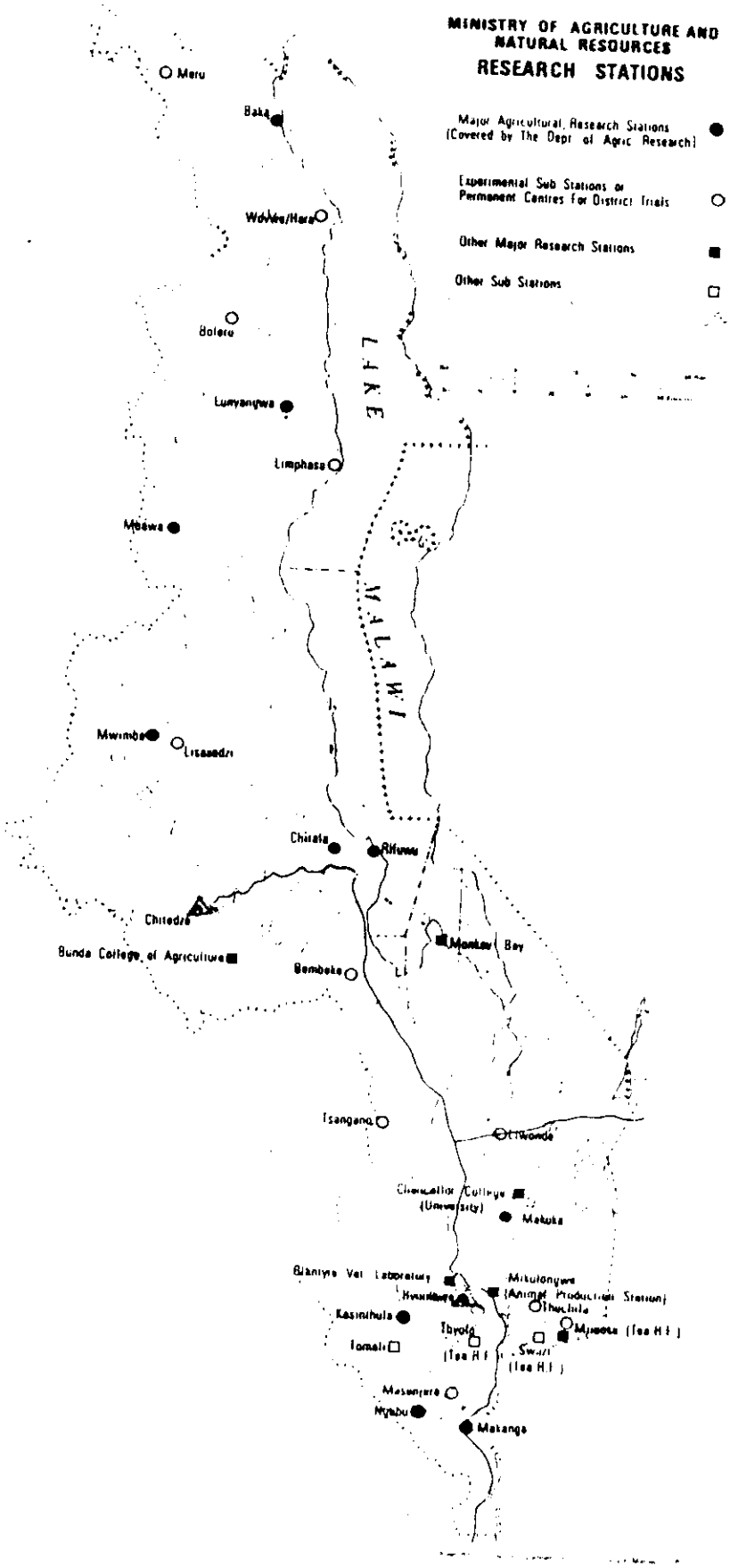
> "Malawi is...an altogether too rare example of an African nation self-sufficient in food. For the last couple of years, it has exported large quantities of grain, and to some extent the country has been able to come to the aid of its drought-stricken neighbors by selling maize...Already this year, more the 40,000 tons of maize has been sent to Zambia...and 50,000 tons is being sent to Zimbabwe". (The African Business, 1984 pp. 50-51).

Malawi has produced agricultural surpluses, enabling export of food, including maize, to drought-stricken neighboring countries. The bulk of production increase resulted from more land cultivation since DAR recommendations were not widely adopted by farmers. (ISNAR, 1982; Department of Agricultural Research, 1983a).

2.2 The Research System Before Reorganization

Malawi's research stations were located over the entire country, as shown in Map 1.0. Disciplinary (agronomy, pathology, etc.) and commodity (maize, groundnuts, livestock, etc.) researchers operated individually --- performing on-station trials without involving the farmers for whom they were doing research. In this system research stations were the focal points (Department of Agricultural Research, 1983a). In addition, poor communi-

MAP 1.0



Map 1. Agricultural research stations in Malawi

cation between research and extension resulted in extension and research staff blaming each other for farmers poor adoption of recommended technologies.

There had been little emphasis on any commodity or discipline. Important crops like maize and groundnuts failed to receive a proportionally greater allotment of the budget over minor crops (IADS, 1983).

2.3. Farming Systems Research

The phrase, farming system research, refers to a more holistic approach of integrating biological and social scientists as they try to understand what farmers do, why they do it and how gradual modifications can be incorporated to increase yield-given limited research resources and time (Collinson, 1979). The proposed innovations are then tested on farms with farmers' full participation throughout the technology generation and evaluation processes.

Four steps were followed in Phalombe, located in Southeastern Malawi. These conform to the general steps for conducting farming system research: 1) review and diagnostic surveys; 2) planning the testing of alternative technologies; 3) testing alternatives; and 4) evaluating the tests, recommending new technologies and

planning the next set of trials (Hansen et al., 1982). Innovations developed through these steps are likely to be acceptable since the innovations are successfully tested on farmers' fields and favorably evaluated by participating farmers.

Because of poor adoption of previous research recommendations and an overall need to upgrade the Research Department, farming systems research was intiated in Malawi in early 1979. Dr. Michael Collinson from CIMMYT demonstrated the diagnostic survey in the Ntcheu Project (South of Chitedze), the first step in a FSR program (Hansen, et al., 1982).

The FSR section in the Department began operating with the arrival of Dr. Art Hansen from the University of Florida in 1981, one year after the diagnostic survey was demonstrated. During the 1981 season, the section conducted three surveys in three areas (Phalombe, Lilongwe and Bulambia plain), with help from agronmists and extension personnel working in these locations. Trials were planned for only two of the three areas because of logistical problems (i.e. one area was too far from Chitedze). Assistance was also given to the Liwonde Agricultural Development Division.

The FSR section focused on priority problems of small farmers and identified opportunities to relieve these constraints. It also assisted the Ministry of Agriculture to identify high priority problems confronting farmers, understand systematic constraints and opportunities, and make recommendations based on on-farm trial results.

The basic responsibilities of the sections were to:

1) coordinate various research disciplines/specialists and extension staff efforts in research and development,

2) develop an understanding of local farm economies and ecosytems through direct involvement in problem diagnosis and constraint identification, and

3) plan gradual modifications to solve problems, and evaluate promising alternatives under farmers' conditions, through the four step process.

In the section's early period, simple trials were mostly designed to test for significant differences between mean yields. Simple answers were sought in most trials, especially those in Phalombe. Analysis of variance was used to test if applying fertilizer made a difference in the yield of two maize varieties (an improved

composite and local maize). The trials in Lilongwe, using a completely randomized design, also tested the response of local maize to fertilizer, but at several levels. While these trials provided preliminary results, detailed trails were needed to investigate the issue in greater detail.

In essence, the goal of the research was to identify the most relevent variables to bring about the greatest contributions to development. However, the effort lacked an analytical focus. Time was spent collecting data without a clear use for it. Numerous other surveys were conducted, in addition to the normal FSR surveys. The section had problems analyzing and presenting findings for use by other sections.

Funding for the FSR section was provided by USAID-University of Florida administered project to strengthen the DAR. The section's research was intended to compliment other research sections (Hansen, 1981). Yet, other members of the DAR were generally hostile to the new section. In contrast, the Extension Department welcomed farming systems research because they saw its potential in bringing relevance to poorly adopted research recommendations.

The FSR section had three full time staff members, including an expatriate from the University of Florida's Department of Anthropology. The other two were new economics graduates from the University of Malawi. Because farming systems are complex, efforts were always made to bring together other relevant biological disciplines each time the group visited farmers or farmers' fields. During the last period (1982) before the FSR program was changed to adaptive research, the group spent considerable time on an extensive data collection exercise in the Lilongwe Project under the tutelage of Dr. Hansen. Minimal analysis was done because the survey was extremely broad, covering all aspects of rural life.

Due to its composition, the section had the potential for undertaking good socioeconomic analysis. However, considerable time was spent on methods of approaching and obtaining information from farmers. Reviewing trial results from Phalombe indicated no clear socioeconomic analysis methodology was ever used by the section.

The section's undertaking show that the FSR methodology, as applied in Malawi was not cost-effective. Given the meager resources in developing countries, researchers must efficiently allocate available research money. The challenge now is how to effectively achieve FSR objectives,

given severe financial and personnel constraints. DAR needs to go beyond the rhetoric of FSR that has obsessed most of the pioneers of the methodology. Too much attention has been given to describing FSR without performing quantitative analyses to help solve the problem of developing recommendations to meet farmers' needs. Researchers in developing countries must seek other ways and means of collecting only data pertinent to them and other departmental researchers.

More emphasis must be on analysis. The current issue is how to proceed after the conversion process, using methods of analysis of farm trial data which build on farm management research, general microeconomic models and sociological methodology.

2.4. Adaptive Research Teams

The FSR section was established in the predominantly station-focus DAR program to seriously take farmers' situations into account. Subsequently, reorganization of the Research Department into commodity and adaptive research teams focused attention on strengthening these teams.

The reorganization of the Department also resulted from poor adoption of recommendations coming out of research station trials. This was well documented in

"The Malawi Agricultural Research Strategy Plan" (Department of Agricultural Research, 1983a). This plan represents a milestone for Malawian agricultural research and is based on the belief that the Research Department could have more influence on the development process. This has been achieved through a reassessment of the scale, structure and functions of the Department to maximize the contribution of the Department to development (Department of Agricultural Research, 1983a).

The eight elements in the new strategy plan include:
1) establishing an Agricultural Research Council responsible for defining agricultural research policies, reviewing and establishing program priorities, and reviewing and recommending research programs and projects. It will be composed of a cross-section of senior government officials and private sector representatives, with a spectrum of disciplines to reduce bias.
2) reorganizing the Department to focus on commodity and adaptive research teams instead of research stations.
3) reorganizing the research station network to reduce overhead costs by closing down some stations and supplementing facilities needed to support commodity teams. In the past, approximately 47 percent of the funds available to the Research Department went to maintaining the

many stations spread throughout the country--some in very similar agro-climatic conditions.

4) strengthening the technical capacity of the Department through advanced training to M.S. and Ph.D levels, non-formal training at international agricultural research centers and institutions, on-the-job training from foreign technical consultants and senior Malawi scientists, and workshops and seminars.

5) taking ample advantage of technologies and services available from international agricultural research centers, African regional research institutions, neighboring countries and other nations.

6) upgrading the systems of planning, budgeting, financial control, monitoring, and evaluation.

7) bringing about close collaboration between education and research through introducing of grants-in-aid or contact research programs. Immediate assistance will be provided to research workers that are expected to be trained to the graduate level at Malawi colleges. Research scientists will be encouraged to teach formal courses at these institutions.

8) making certain research is relevant to farmers' needs by establishing formal links among researchers, extension workers, and farmers (Department of Agricultural Research, 1983a; IADS, 1983).

Because the Department made so many changes at once, there is a strong concern about the possibility of the plan's success. In my opinion, the changes may have been imposed on the research system to reorient biological researchers who seemed content with what they were doing. Although these changes are considered great improvements over the old research system, the old structure appears integrated into the new. The participants' philosophy about research has not changed. These changes may be more cosmetic than real with researchers clinging to the old orientation. Also, the changes may be too numerous for effective management. Finally, the reorganization plan's overriding assumption that people will effectively work together as teams requires careful consideration.

Within the reorganized structure, adaptive research teams play a very significant role in relaying information back and forth between extension workers, farmers, and on-station commodity research groups.

The FSR section's reorganization to adaptive research teams (ARTs) operating out of the main station, took place in 1983 after the FSR section was denied resources for more trials and after the departure of Dr. Hansen at the end of the USAID/UF funded project. The teams were instituted for the same reason as the FSR

section-to develop farm-tested recommendations appropriate for farmers in different zones. The teams ideally were to provide farmer feedback to applied research teams on stations and adapt available technology to local conditions-thereby providing more relevance to the research program as a whole.

The World Bank presently funds the program with training supervised by the East Africa CIMMYT staff. The teams operate pilot projects in two of the eight Agricultural Development Divisions (ADDs). In the near future, as additional Malawians return from graduate training abroad, it is hoped all eight ADDs will be covered.

It is interesting to note that adaptive research leaders define adaptive research as farming systems research. Yet, some team members fail to understand this and do not see the relationship between the ARTs and the old FSR section's undertakings. To add further confusion, some believe that the project is the first one in Malawi and hope CIMMYT researchers will solve their problems for them. Adaptive research is doing exactly what the FSR section was instituted for. The author believes little meaningful work will be done, although the teams will cover all ADDs with more people involved. Therefore, it

would be beneficial to identify lessons learned from the FSR effort to avoid repeating earlier mistakes.

The major difference between the FSR and ART approach lies in leadership and reorganization of the research system. One must realize that station-based teams have undergone minimal changes. It remains to be seen whether the reorganized structure will be more effective and responsive to the farmers' circumstances. Another difference from the FSR section is that the ARTs will operate in the ADDs institutions of the Department of Agriculture which provide extension services among other activities.

2.5. Functions and Objectives of ARTs

ARTs are multi-disciplinary groups comprised of social and agricultural scientists, which involve extension workers to examine smallholder farming systems. This aids in the planning and dissemination of the adaptive research program with the overall objective to provide smallholders with recommendations to increase their resource productivity.

This objective will be achieved through the following six functions:

1) collecting data on different farming systems in each ADD to formulate relevant adaptive and applied research

programs consistent with national and small farmers' goals;

2) carrying out on-farm adaptive research trials;

3) providing an effective link between research and extension through direct involvement of extension workers in problem identification, content and design, management and evaluation of trials, and formulation of recommendations; and continued dialogue with on-station applied commodity teams concerning potential technological solutions and applied research thrusts;

4) providing information describing relevant institutional and infrastructural constraints (i.e., those dealing with the delivery of inputs, input supply, credit and marketing);

5) providing on-the-job training to extension field assistants in day-to-day management of trials and assessment of potential new technologies; and

6) providing information and training to subject matter specialists, development officers, and technical assistants in each ADD to equip them to efficiently communicate developed recommendations to farmers (Adaptive Research section, 1983).

The ARTs will operate in each of the eight ADDs - instead of from Chitedze - the main research station (Map 1.0).

The teams will constantly collaborate with extension workers and also interact with applied commodity research teams through seminars and meetings. The national coordinator -the most senior research scientist- will be based at Chitedze Research Station and be in close contact with the teams as well as other coordinators. Applied researchers (operating under controlled conditions) will work with closely controlled station experiments and their work will trickle down to the adaptive research teams. In each ADD, there will be two agronomists and one socioeconomist as team members--a total of 24 researchers. Although assigned to ADDs, the team members will still be directly under the DAR-- reporting to the coordinator who will report to the Chief Agricultural Research Officer (CARO). The team members are based in ADDs to formalize the link with the Extension Division of the Ministry of Agriculture.

The team members mostly hold B.S. degrees in general agriculture from Bunda College of Agriculture and are expected to be trained at the Master's level. The team members are assigned responsibilities which sometimes stretch outside their general training, including socioeconomic analysis duties. Consequently, the socioeconomic input and analysis are likely to be highly inadequate and

the trials will be no different from those on-stations. They are unlikely going to take into account what the farmers do (ISNAR, 1982). This is reflected in some trials undertaken during the pilot training program in which the treatment levels did not include the common farmers' practice.

The teams will also lack the respect from both extension and other staff on stations because the members are mostly recent graduates with minimal experience. In contrast, other sectors with whom they interact have experienced staff. Thus, it may be difficult to influence them in any meaningful way. There exists a need for strong leadership if the ART's input is to be taken seriously.

While the Farming Systems Section had too much socioeconomic focus, the adaptive research teams have too much of an agronomic focus. A balance between these two perspectives is required in order to serve farmers appropriately. This will also ensure constructive dialogue and criticism when farmers' fields or farmers are visited.

2.6. Other Issues Relating to Adaptive Research Teams

First, in Malawi, the ART's composition suggests no profound socioeconomic analysis will be done. These

teams may only serve the purpose of taking on-station trials to farmers' fields which was already being done. This involves testing technologies under varying environmental conditions, such as rainfall. It must be remembered that FSR was conceived when social scientists discovered recommendations from biological scientists were not being adopted as much as anticipated. If these same biological scientists dominate the program to a point where the social scientist's input is minimum, the same recommendations will be produced and low adoption will follow. In Malawi, for the first year after the ARTs were established, there was virtually no input from farmers in terms of input levels and trial content. After the diagnostic survey, field plots were simply laid out on farmers' fields.

Second, in making recommendations, it must be understood that the economic optima are not constant from season-to-season as existing extension recommendations implicitly assume. Rather, optimum treatment varies according to conditions that change from year-to-year. Adaptive research should seek to understand how changes occur and how the recommendations will change from season-to-season and location-to-location. For example, if input and output prices change substantially, re-analysis of

the data is needed.

Third, the small farmers' world is excessively complex, in fact, more complex than commercial farms in Europe or North America. This complexity is in terms of the environment, available resources, farmers' goals, and institutions (Bernsten, 1980). Taking into account these factors requires rigorous analysis that cannot be taught by short courses conducted by the CIMMYT staff. Training is required for social scientists above minimal MS requirements -- perhaps a few to the Ph.D. level-- with strong training in analytical methods, research methodology and philosophy. This will also help teams to communicate effectively with other teams and thus have more influence on work performed by other teams on stations.

A fourth issue requiring attention is the method of choosing representative farmers. During the pilot program the author took part in some of the work done in one region. The extension field assistant directed the team to friends who did not represent area farmers. These farmers were well off by village standards. A system needs to be devised to select typical farmers involved in these trials. This could be done by asking farmers to cooperate during the first visit and randomly

select a few from this group to participate in on-farm trials.

Fifth, in the early years of adaptive research, more control over trials needs to be exercised so that accurate date for analysis can be obtained. As more and more information becomes available and a clearer picture of relationships evolves, control may be reduced. Too little initial control only results in controversial and inconsistent interpretation of findings. If initial results are confirmed, farmers can then be made responsible for managing these trials for widespread testing of recommendations.

Sixth, there is the problem of funding continuity after the World Bank support comes to an end. One reason the second year's trials were not conducted by the FSR section was that the Department could not afford to finance it as USAID's portion of funding grew smaller. This must be considered now with ways to assure continuity determined. One way of ensuring continuity would be to reduce the cost of the operation as they move to ADDs. The teams should only collect data directly relevant to solving problems. Surveys must be focused so as much information as possible is collected in a single visit. Leaders need to inform teams that cost effective methods

be used wherever possible. FSR work has been performed by institutions or agencies with deep pockets--which is not the case with developing governments.

Finally, little time was spent with farmers. Thus, the levels at which farmers operate were assumed. Interviews were usually hurried and not well focused. This is also due to the use of CIMMYT's overloaded guidelines. More time must be spent during the diagnostic survey so the exact practices or rates farmers use are identified. This information should then be used to establish realistic control rates in on-farm trials.

CHAPTER III

ISSUES IN IMPLEMENTING FARMING SYSTEMS RESEARCH

To create a favourable environment for farming systems/adaptive research, several issues must be effectively addressed. Some of the most important issues as they relate to the Malawi projects are discussed below.

3.1. Communicating Project Objectives

Adaptive research must be carried out with all participants involved in making recommendations to farmers, including extension technicians who are essential to the whole process because they are in constant contact with the farmers. They must understand the objectives of the project, why it was undertaken and how it was decided that adaptive research should be done in Malawi. Otherwise, extension staff may undermine the goals of the project.

For example, extension workers may insist on placing trials on progressive farmers' fields. These progressive farmers must not be ignored, since they too need assistance. Complex trials can be designed on their fields. Yet, the objective must be to get farmers who

represent, as closely as possible, the group of farmers to whom the researchers want the technology extended (Shanner et al. 1981). Although such an exercise was done when the Farming Systems Section was established, it was not reemphasized with the advent of the ARTs. Anyway, in most cases these discussions were held with senior extension workers and the project officer who do not work in the field with the teams.

Also, if the project objectives are not explained clearly, the extension agent will probably think he is being checked on and will have farmers report what he tells them--even when he knows they are not following what he teaches them. Therefore, the agent will always want to take the team to those farmers who remember what he tells them. The team and extension workers must realize that adaptive research is undertaken because recommendations are not widely adopted and that recommended rates are not the levels the farmers are using.

To understand farmers' practices, it may be appropriate to sometimes go out in the area without an extension worker. This will help avoid the problem of farmers reporting the government recommendation instead of their practices.

3.2. Farmer Involvement

Historically, extension workers were supposed to teach the farmers what they should be doing without farmers providing any input. The extension worker was believed to have the knowledge and the farmers the ears to hear what he had for them. For adaptive research to succeed, the thinking of both the farmers and extension workers must be changed.

Extension staff should realize they must learn from the farmers before deciding what changes/improvements to recommend.

To obtain accurate information during surveys, farmers have to be told who the team members are, where they are from and the purpose of their visit. Otherwise, the farmers may think the team has come to give them credit and solve all their problems. When conducting interviews, there is a need to stress to farmers that the team needs to know what they do -- not what the farmer thinks he should be doing. Finally, the ART staff must allow the farmers to ask questions and be careful not to give wrong or false information.

3.3. Understanding the System

FSR/adaptive research is based on understanding

the present system so that changes can be made to improve its overall performance. To understand a given activity, it is necessary to determine exactly what farmers mean by what they say. For example, a farmer may say he plants with the first rains. Such a general answer must be clarified. Rains vary in intensities and duration. It could rain for two days, followed by a dry spell. Some farmers would not consider these the first rains, while some would and may plant their crops. Somehow farmers have a way of knowing when the rains are sufficient to begin planting and the ARTs must try to better understand how farmers decide when to plant.

One should also realize that farmers make mistakes in describing their practices. Farmers may make ridges after the first rains because the ground is wet and plant if they see the rains will continue. If asked, the farmers may say they planted with the first rains when they actually meant they made the ridges with the first rains. These examples illustrate how seemingly known practices are wrongly assumed and therefore wrongly estimated. Thus, the details of the farming activities must be clarified early in the research process.

3.4 Commodity Program-FSR Dialogue

Another issue relates to coordinating adaptive and applied research in the DAR. Success in adaptive research depends on how well the teams relate to applied researchers on stations, and how well farmer's problems are diagnosed and resolved together. Previously, each section has had its own goals, objectives and its own plan of work. If one section, in the course of its own work, obtained useful results which could solve another section's problems, these results were not communicated since there was no mechanism for collaboration and co-ordination between sections. Consequently, there is a need for the coordinators for each commodity and coordinator for adaptive research to define how information from adaptive research teams will be incorporated in their own work (Department of Agricultural Research, 1983).

3.5 The Four Stages of FSR

So far the points made apply to the research system in Malawi and methodological issues requiring attention prior to implementation of the four FSR stages: descriptive and diagnostic, design, testing and extension. The following applies specifically to FSR.

3.5.1. Descriptive and Diagnostic Stage

The objective at this stage is to choose the area, describe the farming system and discover how the present system can be modified.

During this stage, a representative target area is selected in line with national objectives (Shanner, et al., 1981). In the early years of the project, the team tries to select an area where tangible results can be obtained in a short time period to gain credibility. In practice, projects often select an area with the majority of farmers following similar practices. An area where similar practices are followed is known as a reccomendation domain (Perrin, et al., 1976).

After the target area is selected, existing baseline data are collected to exploit all known information about the area. This provides an initial understanding of the area's existing situation. The problem, however, is that often information is not specific enough, if it exists, or no information is available.

During this stage in on-farm studies, biological and social scientists interview the farmers and observe their fields to gain a deeper understanding of the farmers' circumstances. Potential representative sites can

be visited to avoid haphazard selection later. Classification of the target area into recommendation domains can be done using what Hilderbrand (1979) calls the "sondeo", whereby scientists informally interview farmers, and/or with an informal reconnaissance survey (Collinson, 1979). Collinson argues that reconnissance surveys extract the information needed to plan on-farm research, so it becomes a waste of resources to carry out formal surveys unless critical information is missing (Collinson, 1980). In addition, the ARTs should collect supplemental information through semi-formal surveys when trials are in the field and when the team is monitoring on-farm trials.

3.5.2. Design Stage

Following the descriptive stage, on-farm trials are designed, based on the needs and constraints in a particular target area. The relevant strategies are identified to help alleviate identified constraints. At a general level, individual, societal, and national goals should be considered in designing these trials. This is difficult because of conflicts, but in most developing communities farmers are concerned primarily with food self-sufficiency, and money as income. These trials must include some sources of food and income-generating

activities. In Phalombe, trials included a mixture of maize and cowpeas (for food self-sufficiency), and sunflower for money (Hansen, et al., 1982). Farmers need some cash for other needs since total subsistence production is nonexistant.

Specific experimental variables should be chosen that provide the greatest potential to increase the productivity of the most limiting resources (Hansen, et al., 1982; Bernsten, 1985). Treatment levels must include the farmers' practices, government recommendation, and at least some higher level to allow for socio-economic analysis (Bernsten, 1985). Changes in technology must be incremental and recognize that smallholder farmers do not adopt whole packages of technologies at once (Hansen, et al., 1982).

Another issue relates to choosing cooperating farmers to participate in on-farm trials. If the same farmer is chosen every year, the management of that farmer may improve tremendously. As a result, he/she will not be representative of the population. The team needs to verify if the farmers' management improves because of their presence. If so, other farmers should be chosen. On the other hand, it is appropriate to choose the same farmers each year if they did not change their practices

as a result of the researchers' presence. Choosing different farmers every year may be necessary for an overall test of the whole area. After arriving at treatment levels, other factors directly interacting with the treatment levels are monitored. Such factors includes rainfall occurences, duration, etc. These must be identified during this stage so methods of monitoring them can be devised before trials are put in the field.

Locations and seasons affect the level of optimum yields from a set of treatment variable. Therefore, an effort must be made to establish trials in different locations to test if the results can be applied over the whole recommendation domain. Different locations roughly can be demarcated using soil characteristics information, if available. Also, farmers may have some idea of variation within a limited area. Seasonal variations are also common. An estimate of the number of years of trials required can be ascertained by evaluating rainfall data , if available. Three to five years of trials are normally sufficient in one area. Otherwise, the ARTs can obtain a general idea about the frequency of bad years by asking farmers about the frequency of drought because farmers can generally recall this type of information.

3.5.3 Testing Stage

After representative farmers and fields have been selected, and treatment levels and variable identified, trials are conducted to examine and evaluate promising practices under farmers' conditions. In Malawi, researchers manage the test inputs on the farmer's field and the farmer provides everything else. Usually, the performance of technology drops as it is moved from the somewhat artificial experiment station conditions to the farm level and drops even further when the farmer manages the technology.

During the testing process when trials are in the field, there is a great deal of interaction between farmers and research workers. The researchers visit the farmers and interact with them, focusing on how the farmers perceive the improved strategies (Hansen, et al, 1982).

In this stage, labor and other data required for economic analysis are collected. For example, wage rates are collected for different categories of labor and the lengths of time people take to perform a task. In Malawi, data on a per-unit of land basis is not available so a stop watch can be used to collect this data for all areas with trials. Although labor is the most abundant factor of production, it is a constraint during certain operations.

To value family labor, its opportunity cost must be used since family members are not paid in cash. Man-hour equivalents for children and women may not be appropriate if these groups complete the same amount of work as men, as is the case for activities like weeding or applying fertilizer. Unless male labor really does more, there is no need to discount women's or children's work.

During the testing stage on-farm trial data are analyzed (analysis of variance) to identify significant differences between treatment means. In addition ,the data is subjected to economic analysis. Several problems arise in carrying out economic analysis. First, even if output is mainly designated for subsistence some output is sold. Therefore, the price the farmer would incur had he not produced the product himself should be used to value the output. Second, output prices are not constant throughout the year. The price may be quite high during months of severe food shortage, but very low at harvest. Although this has never been done before in Malawi, it would be nice to analyze the data using prices that represent the two extremes (lowest and highest) and an average price for the year. This requires additional work, but can easily be done with a budgeting spreadsheet program, as described in

Chapter Four.

3.5.4 Extension Stage

Results are implemented at this stage. At this point extension personnel are involved to extend the results to the whole recommendation domain (Gilbert, et al., 1980). The researchers must monitor and evaluate the degree of adoption so that lessons can be incorporated into the design of future trials. The ART must determine the number of farmers adopting the improved technology and identify reasons for any divergence from the existing recommendations. While some deviation is expected because farmers usually want to try something before they devote all their resources to it, poor adoption may indicate a need for further testing to better meet farmers' needs (Harrington, 1980).

In practice there are no clear boundaries between these four stages. Information obtained at any stage may serve as a basis to refine research priorities, design new trials and reanalyze on-farm trial results.

CHAPTER IV

ECONOMIC MODELS FOR EVALUATING ON-FARM DATA

4.1 ECONOMIC MODELS

Much of the foregoing discussion described the Department of Agricultural Research. In this chapter, Economic models will be applied to data collected by the Department.

If farmers' goals and economic parameters such as prices are not taken into consideration, it is impossible to determine how farmers will assess the technology, regardless of the yield response. For this reason, statistically significant results may not be very attractive to farmers. This does not mean that statistical analysis is of no value. It is useful in determining the biological response in the experiments. But in addition, economic analysis is needed to assess the profitability of recommendations. Economic models are appropriate for modeling the farm situation - assuming farmers roughly and indirectly evaluate technology in terms of benefits and costs.

Economic analysis can be presented in two complementary ways. There are those models that address the direct profitability of an enterprise and those which

assess the total feasibility of all recommendations. Because of a shortage of data and the limited sccpe of this paper, the latter will only be discussed while the former will be illustrated using agronomic experimental data. In addition to a discussion of economic models, variability over space and time is discussed with sensitivity analysis performed in the illustration. This is by way of changing prices only.

Smallholder farmers are mainly concerned with food self-sufficiency, although they need some cash to purchase essentials (Hansen, et al., 1982). Although profit maximization is a simplification of their overall objective, it is a realistic assumption on which to base our analysis.

4.1.1. Simple Benefit Cost Analysis

Purpose

The purpose of simple benefit cost analysis is to evaluate the attractiveness of recommendations in terms of benefits and costs to the farmer (Dillon and Handaker, 1980).

Trials which may be analyzed in terms of simple benefit cost analysis are usually designed to answer yes/no questions and are exploratory in nature. The method measures the relative profitability of two treatment levels or variables. An example would be comparing

a single recommendation with the farmers' practice.

Data

The type of data needed are the costs of the incremental inputs, the yield of the control and the treatment and the prices(s) of the output(s) produced. The analysis attempts to determine which treatment gives higher profit.

Analysis

These trials allow the researcher to easily conclude which one of the two alternatives has a greater impact on yield and profitability-making it possible to ccncentrate on refining treatments in subsequent trials.

Advantages and Disadvantages

Simple benefit cost analysis has limitations. The technology cannot be analyzed indepth because there are only two treatment levels. As there is only one comparison, it will be impossible to know if there are other possibly more profitable alternatives. Thus, the two levels will probably not include the profit maximizing input level. Simplicity is the only advantage.

4.1.2. Marginal Benefit Cost Analysis

Purpose

The purpose of marginal benefit cost analysis is

to compute the ratio of the rates of increase of benefit to costs at several incremental treatment levels (Perrin, et al., 1976).

Data

With multiple treatments, it is possible to approximate the economic optimum, in that there will be at least more than one comparison. To perform this analysis, the trials must have at least three treatment levels: the farmer's practice, the recommended practice and some level higher than the recommended level. The farmer's practice is estimated through surveys (formal as well as informal). For this analysis, data is needed on the costs of all inputs including labor input for each treatment. Sometimes the opportunity costs must be estimated where there are no money transactions. Yield figures of the treatments must be collected as well as the price per unit of output--which could be either the official announced price or some local selling price. For output not sold, the oppcrtunity field price should be estimated based on what the farmer would receive for the product if he sold it. In Malawi, one problem with the official price is that it is the lowest price the farmers get at harvest. The farmers could sell the same product for more than twice the official price two or three months

after harvest when the product is less abundant. It would be a good idea to roughly estimate how prices actually vary because prices are not constant throughout the season. Then, include both the official and the highest possible price in estimating the value of the product.

Analysis

Marginal benefit cost analysis considers only the cost of inputs which are variable. In the process, benefits are obtained by multiplying net yield with price per unit of that output for all the treatment levels. The costs for all the variable inputs are calculated by multiplying the amount of the input by the price of that input when money transactions are involved. On the other hand, for non-cash transactions opportunity costs are estimated (Perrin, et al., 1976). Family labor falls in this category. After the benefits and costs are estimated, the researcher arranges the treatments in descending order according to net benefits (gross benefit minus costs). Dominant treatments are selected by comparing benefits and costs of each. This process eliminates those treatments yielding lower benefits, but which are more expensive than others yielding the same or higher net benefits with lower costs. These dominated

treatments are the ones that farmers will not follow, so further analysis is not required.

After the dominant treatments have been selected, the costs of those treatments are put side by side with the net benefits. The analysis proceeds to estimate the marginal benefits and costs. The marginal rate of return to the variable factor is calculated by dividing marginal increase in benefits by marginal increase in costs of adjacent treatments for all the treatment levels. As a rule of thumb this rate must exceed 40 percent given the severe scarcity of capital in developing countries (Perrin, et al., 1976). This level is subjective though. This is interpreted as the expected return to investment in the variable factor of production. Any return of greater than 40 percent will likely appeal to farmers.

The best treatment is the one with the highest rate of return. The analysis can be taken further to incorporate risk. This entails examining the variability of results. If minimum returns analysis shows that the results are not so variable; then the input level is a recommendation that has a high chance of being adopted (Dillon and Hardaker, 1980).

The overall aim of this analysis is to derive

recommendations consistent with farmers' desires to increase expected income, to avoid risk and to make the best possible use of the farmer's scarce resources (Dillon and Hardaker, 1980).

Advantages and Disadvantages

The advantages of marginal analysis include ease of performing the analysis, the needed data can be obtained easily from designed trials, and farmers can understand the trials--making the analysis appropriate for on-farm research. Another advantage is that the method uses only costs that vary so that only the costs of a few items are needed for the analysis. For example, fixed costs are excluded. The marginal analysis is in line with the overall objective of on-farm research to introduce marginal changes into the present farming system.

The major disadvantage is that costs and benefits at the treatment levels are evaluated. The most profitable level might be between the treatment levels. In this case, profit is not maximized as it would be if a continuous function was used in estimating the response curve between treatment levels (Heady and Dillon, 1964).

4.1.3. Production Function Analysis

A production function is a quantitative relationship between inputs and output, which can be verbal, tabular, geometric or algebraic. The estimation and analysis of such relationships are production function analysis (Dillon and Hardaker, 1980).

This type of analysis is more analytically complex than marginal benefit/cost analysis. Therefore, it is difficult to apply to the real world situations without problems. It is based on more complicated theory than any other analysis discussed here.

The method is not appropriate for individual farm analysis, but only to guide government policymakers about recommendations to farmers (Dillon and Hardaker, 1980). For more detail, see Heady and Dillon, (1964).

Choice of Function, Data and Estimation Procedure

The choice of a function to use is subjective, although guidence can be provided by the following considerations: goodness of fit as depicted by R^2 or corrected R^2; *a priori* economic and physical logic; ease of analysis for manipulation to find the marginal physical product (for example); and the researcher's judgment of implications to be drawn from the estimates (Dillon and Hardaker, 1980). The choice of functions is narrowed

down to three which are usually adequate. These are the power, the quadratic and the square root functions. The quadratic function is usually preferred because results can easily be used to identify optimum input levels.

Given experimental data with various input levels (usually per hectare or animal), the function is estimated by use of least squares regression procedures for a single dependent variable (Y) and one or more independent variables. With the advent of the computer, multiple regressions programs to do the analysis are readily available. One needs only to enter the levels of the independent variable, the yield, and to specify the model being used. After all is entered, the program estimates the parameters. Once the parameters are estimated, economic analysis follows the established methodology in maximizing profit to be discussed in the following sections. The discussion is in terms of one equation as opposed to simultaneous equations.

The Optimization Process

(i) No Constraints

Given that a function has been chosen and parameters estimated from the data, estimating the input levels that maximize profit involves equating the marginal

physical product for each input to the price ratio (input-output). The marginal physical product is found by partially differentiating the estimated function (total physical product) with respect to each input. The process basically involves equating the marginal value product (MVP) to the marginal factor cost (MFC). The MVP is the same as the value of the marginal product when the output price is constant and the quality of the product remains the same. The MFC is the per unit input cost--the price of an additional unit of input when discounts due to bulk buying are not considered. The marginal value product can be obtained by differentiating the total value product function (which is the totally physical product multiplied by the unit price of output to get the function into value terms) and this has to equal the unit price of the input which is also the MFC.

The process is done for any number of inputs in the function and a solution to the equations so formed may be found. This method is appropriate for fertilizer trials where no fixed costs are a major component of the introduced technology.

(ii) With Constraints

For farmers, especially in developing countries,

capital is scarce. The type of analysis to deal with constraints uses other related economic criteria in the specification of input quantities. For example, farmers may be willing to settle for less than the maximum profit level, given their limited capital outlay. Therefore, in such a situation a minimum input requirement can be defined and, coupled with the maximum profit point, farmers can decide what level to use. In essence, this defines the range over which profit can be made (from zero profit (minimum) to maximum profit). The maximum level is identical to case (i) above and the minimum is where no profit is made.

Advantages and Disadvantages

The main advantage of production function analysis is that finite levels of input use may easily be determined without being confined to the levels of input actually used in the trial. However, there are serious problems with its use, some of which are outlined below.

It is difficult to interpret results from production functions. There is also uncertainty about the effect of uncontrolled factors excluded from analysis which interact with experimental treatments. Data for estimation may be imperfect, thereby obtaining unrepresentative parameters. While the estimated function can

be interpreted as an average relationship across some set of (hopefully representative) observations, there are problems with averages. Parameters are interpreted as holding all other factors in the equation(s) fixed. Another problem is that complex trials are required to obtain the necessary data. Yet, on-farm research needs farmer input and understanding which diminishes with increasing complexity of designs. On the other hand, the complex designs depict as accurately as possible the production surface, so that no combination is excluded from the experimental trials. These problems make the use of production function analysis inappropriate for evaluating on-farm data.

4.1.4. Feasibility Programming Models

The profitability measures discussed above estimate profitability on an individual enterprise or crop basis. They do not take into account the feasibility of each of the chosen levels of input in the context of the whole farm. The feasibility issue is addressed by models that consider the profitability of the whole farm in determining the most profitable enterprise/crop combination for a farm to maximize an objective such as profit. Some of the models are simplified programming and linear programming and only these two will be discussed in this paper.

Before recommendations are made, economists should evaluate how recommendations actually perform together, given farmers limited resources. There are recommendations from Malawi that are not feasible in the eyes of the farmer specifically because they were developed separately and never considered together. One such example is the planting time for crops. The recommendation states that each crop must be planted with the first rains, but farmers cannot get all their crops in at once. They plant them in order of their importance because there is a severe labor bottleneck during that time. The only alternative is to plant some of the less profitable or less preferred crops sometime after the first rains.

Simplified Programming

Simplified programming is a valuable tool where information is available on available resources, constraints, and yield or output levels of enterprises. It helps determine the mixture of crops and livestock to maximize net income from a given bundle of resources. The required calculations are done by hand and as a result, a limited number of enterprises can be considered. A hand calculator may be handy too.

There are variations to the methodology. The approach discussed here is described by Weathers (1964). The exercise first involves preparing enterprise budgets in terms

of each resource requirement and net income per acre or unit of livestock. The analyst then takes an inventory of a farmer's available resources as accurately as possible. The process then becomes one of adding enterprises, one by one, with those yielding the highest net income coming in first. This exhausts the most constraining resources. Essentially this principle involves maximizing net farm income by first using up each limiting resource in its highest profit use. Weathers employs three tables to complete the analysis. These tables contain the following information and constitute the data requirements for the analysis.

The first table contains the resource requirements. The second table shows the maximum amounts of each enterprise, as if each were the only one in the solution. This takes into consideration the most limiting resource for that activity. The third table presents returns per unit of resources. For more detail consult Weathers (1964). After these tables are prepared, a procedure for selecting the combination of enterprises to maximize net income is followed. This procedure involves first considering those enterprises with the highest return, then the next etc., until all resources are used up.

An advantage, compared to other programming methods, is that no computer is required. With a small number of enterprises and constraints considered (at most 10 enterprises), the solution will usually be very close to the optimum (Weathers, 1964). There are rules to guide the inexperienced in the exercise. These rules are straightforward and easy. In developing countries, although computers may be available, access is a problem, which makes this method appropriate. Considering the fact that most small farmers have only a few enterprises to consider and have fewer constraints than large farms, this procedure seems appropriate. However, programming their cases may not be easy due to their high degree of subsistence and use of household resources.

Disadvantages include the long amount of time required for calculations, the limited number of activities and constraints included so that reality may not be represented, and the difficulty of taking into account interrelationships among activities. On the other hand, these limitations can be nicely incorporated in linear programming, as discussed below.

Linear Programming

Linear programming is a procedure that uses more complex analysis than simplified programming because it

is computer generated. The final solution will only comprise of enterprises maximizing the income to the farmer or households.

The needed information is presented in an initial matrix of available resources, amounts of each required per task, returns per unit and the constraints on the activities in the matrix. The matrix can be made as large as is appropriate. There is no problem finding the solution since the computer does all the computations using programs that have been developed and are used widely. The method employed is similar to what is done in simplified programming.

The major advantage is the method's use of a computer which can process enormous amounts of data efficiently. Other advantages include the generation of additional economic information about the optimal solution and some supplementary information like the range in which the optimal solution will hold. This information will show how stable the optimal solution is, considering changes in prices and costs of resources. These ranges are computed for activities in the solution as well as those that are not included in the optimal plan.

However, a disadvantage is that the method requires a computer and requires experience in how to correctly

program the analysis to get the desired solutions. It is also time-consuming to construct the matrix and process data for computer analysis. There are also the problems inherent in the assumptions on which the technique is based (Dillon and Hardaker, 1980). Linearity assumes constant returns to scale applies to each activity. Also, linear programming makes the simplifying assumption that all activities and resources are infinitely divisible. This problem may be alleviated by using integer programming, although its routines are less widely available and more complex. The last limitation involves risk. No account is taken of risk, which is perhaps a very serious issue for small farmers operating under severe weather fluctuations since these fluctuations cause variability in returns to input use. For more detail on linear programming, see Heady and Chandler (1958).

4.1.5. Variability Over Time and Space

For trials to be respresentative, they must cover a sufficient number of locations, years, or seasons. With regard to location, the researchers must judge the representativeness of each trial site with respect to the areas where recommendations will be made. The more homogenous the area, the fewer the number of experimental

sites needed to represent it and vice versa. The same principle applies to seasons. Some areas have very homogeneous conditions from year-to-year. This can be roughly observed from rainfall data. In general, at least three years of trials are required before reliable recommendations may be made.

Profitability and feasibility of recommendations often assume away the fact that yields fluctuate over time (i.e. between seasons) and space (i.e. location-to-location). Failure to consider risk has serious consequences when such fluctuations cause yields to fall below the farmers' food self-sufficiency requirement.

Also, within a single year and on a single site, yield varies due to differences between the same treatments in different replications within that site. This is not a serious problem--it simply corresponds to the usual variation faced by farmers in a particular field. The farmers automatically allow for this variation (Dillon and Hardaker, 1980). This is also why trials are replicated--so that an average picture is obtained.

Thus, the problem requiring further consideration is the variability over the years and over locations within the target area which results in different levels of return to farmers that may jeopardize their existence.

Minimum returns analysis (MRA) is used to examine the riskness of recommendations. The procedure followed in MRA is to appraise the worst 25 percent of the outcomes of each alternative (Perrin et al., 1976). Net returns for the worst 25 percent of the outcomes are computed and the best of these 25 percent are assumed to be less risky in that the farmer who is concerned about occasional low returns cannot do better than achieve the best of the worst. When experimental data is used, even abandoned trials (and plots within trials) must be included so long as they were abandoned due to constraints confronting the farmer. Trial treatments should only be excluded if farmers do not commonly face the circumstances causing the loss.

Another source of variability is due to price fluctuations. In most cases, the researcher is not directly involved in policy making. Yet, the researcher can provide important input to policy makers through sensitivity analysis. This entails changing the levels of prices to show how recommendations will vary, holding everything else constant. In the illustration presented in this paper, prices are varied to show the impact of various input and output prices on profitability. This type of analysis is not currently done in Malawi (ISNAR, 1982).

4.2. ILLUSTRATIVE ANALYSIS USING SELECTED ECONOMIC MODELS

4.2.1. Data Sources

Data used to illustrate the following economic analysis were obtained from trials conducted on farmers' fields in Malawi during the existence of the FSR section. The other set of data came from the trials done by the ARTs during the pilot program (1983/84). The data were obtained in the Dowa-West project in Kasungu Agricultural Development Division (one of the eight agricultural development divisions of Malawi). Input and output prices used were mainly those in effect during these seasons.

Both variety and fertilizer levels are evaluated. The variety trial was conducted by the Farming Systems Research Section while the fertilizer levels trial was conducted when the section was reorganized into ARTs. The variety trial was designed to evaluate whether or not Chitedze Composite A (CCA) performed better than local maize under farmers' conditions. The fertilizer trial was designed to investigate the response of local maize to fertilizer.

4.2.2. Analytical Tools

The statistical analysis package, MSTAT, Supercalc and PC-Calc will be used. Economic analysis will be done using Supercalc and PC-Calc, electronic spreadsheet programs.

4.2.3. The Illustrative Analysis

4.2.3.1. Variety x Fertilizer Trial

The trial was designed to test two varieties - local maize and Chitedze Composite A (CCA)-at two levels of fertilizer (zero fertilizer vs. the recommended rate of two bags Sulphate of Ammonia and one bag 20:20:0 per acre.) An acre is approximately two fifth of a hectare and a bag of each type of fertilizer weighs 50 kilograms. The trial was conducted in two villages where sixteen farmers participated.

Statistical Analysis

Yield figures in metric tons per hectare are shown in Table 4.1. Since MSTAT cannot do analysis of variance with an unequal number of farmers in the two villages and the Malawi staff had already evaluated the trial using ANOVA, these results are used and presented in Table 4.2.

Table 4.2. shows that maize variety was non-significant in both villages and when combined. The two varieties performed the same generally in both villages (i.e. CCA did not yield significantly better than local maize). Also, the interaction between the fertilizer and the two maize types was non-significant, implying generally similar response from both varieties.

Table 4.1

Maize Yields On On-Farm Farmer-Managed Trial,

Phalombe, Malawi, 1981/82. (M.T./ha)

TREATMENTS	FIRST VILLAGE FARMER COOPERATORS								
	1	2	3	4	5	6	7	8	Mean
Local Maize	2.2	2.2	1.9	1.2	1.3	0.9	1.0	0.5	1.4
Fert. Local(LM-F)	3.6	3.7	4.3	3.2	2.3	2.3	3.1	2.8	3.1
CCA Maize(CCA)	3.5	2.0	2.9	0.4	0.6	0.5	0.6	0.2	1.5
Fert.CCA(CCA-F)	5.0	4.7	4.3	3.5	2.4	1.7	3.0	1.3	3.1
Mean for farmers	3.6	3.2	3.3	2.1	1.7	1.3	1.9	1.0	2.3

SECOND VILLAGE

TREATMENTS	SECOND VILLAGE FARMER COOPERATORS						
	1	2	3	4	5	6	Mean
Local Maize (LM)	1.8	1.1	1.6	1.0	1.6	0.6	1.3
Fert. Local (LM-F)	3.2	2.5	2.9	1.2	1.9	0.8	2.1
CCA Maize	2.2	0.7	0.9	0.3	1.1	0.3	0.9
Fert. CCA (CCA-F)	2.9	2.9	2.1	1.1	0.9	0.4	1.6
Mean for farmers	2.5	1.7	1.9	0.9	1.4	0.5	1.5

Source: Farming Systems Research Section, DAR.

TABLE 4.2

Analysis of Variance Results, Phalombe, Malawi, 1981-82(a).

SOURCE OF VARIANCE	DEGREES OF FREEDOM	MEAN SQUARE	F RATIO	SIGNIFICANCE
FIRST VILLAGE				
Farmers (8)	7	3.947	2.41	94%
Fertilizer (2)	1	25.740	15.74	>99%
Maize Type (2)	1	0.428	0.26	non-significant
Fert x Maize	1	non-significant		
Error	21	1.653		
SECOND VILLAGE				
Farmers (6)	5	2.049	3.53	97%
Fertilizer (2)	1	3.450	5.94	97%
Maize Type (2)	1	1.000	1.72	non-significant
Fert x Maize	1	0.010	non-significant	
Error	15	0.581		
COMBINED VILLAGES				
Villages (2)	1	11.550	10.83	>99%
Fertilizer (2)	1	25.515	23.93	>99%
Maize Type (2)	1	0.026	non-significant	
Vill x Fert	1	3.676	3.45	93%
Vill x Maize	1	1.403	1.32	non-sigificant
Fert x Maize	1	non-significant		
Error	49	1.066		

a) In the analyses for individual villages, the smallholders are used as blocks, and there is only one replication of each treatment per block. In the analysis of the combined villages, the villages are used as blocks, and there are eight replicates (farmers) in the first village/block and six in the second.

Source: Farming Systems Research Section, DAR.

The other important results include:

a) Farmers were significantly different. Some obtained low yields while others obtained very high yields with the same treatments.

b) Fertilizer application was highly significant, indicating that applying fertilizer to both varieties significantly increased yields.

c) That villages were highly significant, indicating that the treatments performed quite differently in each village (Table 4.2).

Economic Analysis Using Benefit Cost Analysis

Due to the fact that only two fertilizer levels were tested, simple benefit cost is the appropriate analytical measure. The profitability of varieties and fertilizer levels was estimated using PC-CALC (See Appendix I). Analysis was performed for each village because the ANOVA showed the response was different between villages. There was also a sensitivity analysis done.

First Village; Simple Benefit Cost Analysis

Using 1982/83 prices for maize and fertilizer, the economic analysis results shown in Table 4.3 indicate that applying fertilizer to both maize varieties produced a positive rate of return. These rates of return for

TABLE 4.3

Simple Benefit Cost Analysis of Two Levels of Fertilizer Application on Local and Improved Maize, Phalombe, Malawi, 1981-82.

FIRST VILLAGE

PRICE OF 50 KG OF FERTILIZER

CAN	10.00
20:20:0	8.50
S/A	8.00
FIELD PRICE OF MAIZE (MT)	110.00
ADJUSTED PRICE	99.00

	LOCAL		CCA	
	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer
Average Yield (MT/Ha)	1.40	3.20	1.30	3.40
Adjusted Yield(Net)[a]	1.26	2.88	1.17	3.06
Gross Benefit[b]	124.74	285.12	115.83	302.94
No. of bags/acre[c]				
CAN	.00	.00	.00	.00
20:20:0	.00	1.00	.00	1.00
S/A	.00	2.00	.00	2.00
Variable Costs				
Fertilizer cost (K/acre)	.00	24.50	.00	24.50
Fertilizer cost /Had	.00	61.25	.00	61.25
Application	.00	6.25	.00	6.25
Seed	.00	.00	6.25	6.25
Total Variable Costs	.00	67.50	6.25	73.75
NET BENEFIT[e]	124.74	217.65	109.58	229.15
Return to K1.00 Invested	N/A	1.376	negative	1.416

Source: Farming System Research Section and official prices from a parasta tal.

a) Average yield times discount factor of 0.90.

b) Gross benefit = net yield times adjusted price(Field price adjusted 10 percent down).

c) 1 bag =50kg.

d) The costs per acre were converted to costs per Hectare.

e) Net Benefit = Gross Benefit - total variable cost.

Note: K1.00 is approximately $0.60 (U.S.)

local maize and CCA. were 38 and 42 percent respectively. For each Kwacha invested in each variety, the farmer received K1.38 for local maize and K1.42 for CCA. Using a 40 percent increase as the necessary rate of return, applying fertilizer on CCA met the requirement, but applying fertilizer to local maize gave less than a 40 percent return.

The tentative recommendation here will be to apply fertilizer on CCA. However, further verification of these results is needed since the analysis is only based on one year of data. In order to identify the real economic optimum, a multi-level fertilizer trial is needed. Because only one level was used in this trial, it is unlikely that the most profitable level of application of fertilizer has been identified.

First Village: Sensitivity Analysis

In the sensitivity analysis, prices of either inputs or output were varied. The results are shown in Tables 4.4 through 4.6. In Table 4.4, the question asked was "What if the price of maize changed to K122.00/M.T., holding input prices fixed?". This was the price in the 1983/1984 season.

The two maize varieties both give a return on

fertilizer over 60 percent (Table 4.4). The rates of return to investment are almost the same for both local and the improved maize variety. Therefore, applying fertilizer to both varieties more than meets the 40 percent requirement. On the other hand, local maize without fertilizer out-performs CCA without fertilizer, giving net benefits of K138.35 and K122.22, respectively.

In Table 4.5, 1983/84 fertilizer prices and the new maize price for that year were used. The rates of return are well below 40 percent. The return to K1.00 invested is only K0.17 and K0.24, for local and CCA, respectively. This indicated that it was not profitable to use fertilizer on the two varieties, given new imput and output prices. As was the case using 1982/83 prices, growing local maize without fertilzer yielded a higher net benefit than growing CCA without fertilizer (K138.35 versus K122.22/ha).

In Table 4.6, the maize price was raised to K150.00/ M.T. The result also indicates low returns per Kwacha invested. Returns per Kwacha invested were K0.43 and K0.53 for local maize and CCA, respectively. As previously stated, applying fertilizer on both maize varieties does not seem to be profitable since these are well below 40 percent.

TABLE 4.4

Sensitivity Analysis Using 1983-84 Maize Price.

FIRST VILLAGE

PRICE OF 50 KG OF FERTILIZER

CAN	10.00
20:20:0	8.50
S/A	8.00

FIELD PRICE OF MAIZE (MT)	122.00
ADJUSTED PRICE	109.80

	LOCAL		CCA	
	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer
Average Yield (MT/Ha)	1.40	3.20	1.30	3.40
Adjusted Yield(Net)[a]	1.26	2.88	1.17	3.06
Gross Benefit[b]	138.35	316.22	128.47	335.99
No. of bags/acre[c]				
CAN	.00	.00	.00	.00
20:20:0	.00	1.00	.00	1.00
S/A	.00	2.00	.00	2.00
Variable Cost				
Fertilizer Cost (K/acre)	.00	24.50	.00	24.50
Fertilizer Cost/ Ha[d]	.00	61.25	.00	61.25
Application	.00	6.25	.00	6.25
Seed	.00	.00	6.25	6.25
Total Variable Costs	.00	67.50	6.25	73.75
NET BENEFIT[e]	138.35	248.72	122.22	262.24
Return to K1.00 Invested	N/A	1.635	negative	1.679

Source: Farming System Research Section and official prices from a parastatal.

a) Average yield times discount factor of 0.90.

b) Gross benefit = net yield times adjusted price (Field price adjusted 10 percent down).

c) 1 bag =50kg.

d) The costs per acre were converted to costs per hectare.

e) Net Benefit = Gross Benefit - total variable cost.

Note: K1.00 is approximately $0.60 (U.S.)

TABLE 4.5

Sensitivity Analysis Using 1983-84 Maize and Fertilizer Prices.

FIRST VILLAGE

PRICE OF 50 KG OF FERTILIZER

CAN	17.50
20:20:0	20.50
S/A	19.00
FIELD PRICE OF MAIZE (MT)	122.00
ADJUSTED PRICE	109.80

	LOCAL		CCA	
	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer
Average Yield	1.40	3.20	1.30	3.40
Adjusted Yield(Net)[a]	1.26	2.88	1.17	3.06
Gross Benefit[b]	138.35	316.22	128.47	335.99
No. of bags/acre[c]				
CAN	.00	.00	.00	.00
20:20:0	.00	1.00	.00	1.00
S/A	.00	2.00	.00	2.00
Variable Cost				
Fertilizer Cost (K/acre)	.00	58.50	.00	58.50
Fertilizer Cost/ Ha[d]	.00	146.25	.00	146.25
Application	.00	6.25	.00	6.25
Seed	.00	.00	6.25	6.25
Total Variable Costs	.00	152.50	6.25	158.75
NET BENEFIT[e]	138.35	163.72	122.22	177.24
Return to K1.00 Invested	N/A	0.166	negative	0.245

Source: Farming System Research Section and Official Prices from a parastatal.

a) Average yield times discount factor of 0.90
b) Gross benefit = net yield times adjusted price (Field price adjusted 10 percent down).
c) 1 bag =50kg.
d) The costs per acre were converted to costs per Hectare.
e) Net Benefit = Gross Benefit - total variable cost.

Note: K1.00 is approximately $0.60 (U.S.)

TABLE 4.6

Sensitivity Analysis using a Hypothetical

Maize price (K150/M.T.) and 1983-84 Fertilizer Prices

FIRST VILLAGE

PRICE OF 50 KG OF FERTILIZER

CAN	17.50
20:20:0	20.50
S/A	19.00
FIELD PRICE OF MAIZE (MT)	150.00
ADJUSTED PRICE	135.00

	LOCAL		CAA	
	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer
Average Yield	1.40	3.20	1.30	3.40
Adjusted Yield (Net)[a]	1.25	2.88	1.17	3.06
Gross Benefit[b]	170.10	388.80	157.95	413.10
No. of bags/acre[c]				
CAN	.00	.00	.00	.00
20:20:0	.00	1.00	.00	1.00
S/A	.00	2.00	.00	2.00
Variable Cost				
Fertilizer Cost (K/acre)	.00	58.50	.00	58.50
Fertilizer Cost/ Ha[d]	.00	146.25	.00	146.25
Application	.00	5.25	.00	6.25
Seed	.00	.00	6.25	6.25
Total Variable Costs	.00	152.50	6.25	158.75
NET BENEFIT[e]	170.10	236.30	151.70	254.35
Return to K1.00 Invested	N/A	0.43	negative	0.53

Source: Farming System Research Section and Official Prices from a parastatal.

a) Average yield times discount factor of 0.90

b) Gross benefit = net yield times adjusted price (Field price adjusted 10 percent down).

c) 1 bag = 50kg.

d) The costs per acre were converted to costs per Hectare.

e) Net Benefit = Gross benefit - total variable cost.

Note: K1.00 is approximately $0.60 (U.S.)

Second Village: Results

The second village had lower average yields than the first (Table 4.1). Economic analysis results are shown in Tables 4.7 through 4.10. For 1982-83 prices only local maize yielded a positive return per Kwacha invested in fertilizer (Table 4.7), but the return was only K0.06 per K1.00 invested. When the price of maize was increased to K122.00 (Table 4.8), the return to fertilizer increased to a low of K0.17 for local maize and remained negative for CCA. Increasing the price of fertilizer and the maize price to the 1983-84 levels (Table 4.9) and increasing the maize price to K150 but using the 1983-84 fertilizer prices (Table 4.10) gave negative returns in both cases.

With these yields and the prices used, it is not advisable to use any fertilizer in the second village on the two maize varieties tested.

TABLE 4.7

Simple Benefit Cost Analysis of Two Levels of Fertilizer Application on Local and Improved Maize, Phalombe, Malawi, 1981-82.

SECOND VILLAGE

PRICE OF 50 KG OF FERTILIZER

CAN	10.00
20:20:0	8.50
S/A	8.00
FIELD PRICE OF MAIZE (MT)	110.00
ADJUSTED PRICE	99.00

	LOCAL		CAA	
	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer
Average Yield	1.30	2.10	.90	1.60
Adjusted Yield (Net)[a]	1.17	1.89	.81	1.44
Gross Benefit[b]	115.83	187.11	80.19	142.56
No. of bags/acre[c]				
CAN	.00	.00	.00	.00
20:20:0	.00	1.00	.00	1.00
S/a	.00	2.00	.00	2.00
Variable Cost				
Fertilizer Cost (K/acre)	.00	24.50	.00	24.50
Fertilizer Cost/ Ha[d]	.00	61.25	.00	61.25
Application	.00	6.25	.00	6.25
Seed	.00	.00	6.25	6.25
Total Variable Costs	.00	67.50	6.25	73.75
NET BENEFIT[e]	115.83	119.61	73.94	68.81
Return to K1.00 Invested	N/A	0.06	negative	negative

Source: Farming System Research Section and Official Prices from a parastatal.

a) Average yield times discount factor of 0.90.
b) Gross benefit = net yield times adjusted price (Field price adjusted 10 percent down).
c) 1 bag = 50kg.
d) The costs per acre were converted to costs per Hectare.
e) Net Benefit = Gross Benefit - total variable cost.

Note: K1.00 is approximately $0.60 (U.S.)

TABLE 4.8

Sensitivity Analysis Using 1983-84 Maize Price.

SECOND VILLAGE

PRICE OF 50 KG OF FERTILIZER

CAN	10.00	
20:20:0	8.00	
S/A	8.00	
FIELD PRICE OF MAIZE (MT)		122.00
ADJUSTED PRICE		109.80

	LOCAL		CAA	
	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer
Average Yield	1.30	2.10	.90	1.60
Adjusted Yield(Net)[a]	1.17	1.89	.81	1.44
Gross Benefit[b]	128.47	207.52	88.94	158.11
No. of bag/acre[c]				
CAN	.00	.00	.00	.00
20:20:0	.00	1.00	.00	1.00
S/A	.00	2.00	.00	2.00
Variable Cost				
Fertilizer Cost (K/acre)	.00	24.50	.00	24.50
Fertilizer Cost/ Ha[d]	.00	61.25	.00	61.25
Application	.00	6.25	.00	6.25
Seed	.00	.00	6.25	6.25
Total Variable Cost	.00	57.50	6.25	73.75
NET BENEFIT[e]	128.47	140.02	82.69	84.36
Return to K1.00 Invested	N/A	0.17	negative	negative

Source: Farming System Research Section and official prices from a parastatal.

a) Average yield times discount factor of 0.90.

b) Gross benefit = net yield times and adjusted price (Field price adjusted 10 percent down).

c) 1 bag =50kg.

d) The costs per acre were converted to costs per Hectare.

e) Net Benefit = Gross Benefit - total variable cost.

Note: K1.00 is approximately $0.60 (U.S.).

TABLE 4.9

Sensitivity Analysis Using 1983-84 Maize and Fertilizer Prices.

SECOND VILLAGE				
PRICE OF 50 KG OF FERTILIZER				
CAN	17.50			
20:20:0	20.50			
S/A	19.00			
FIELD PRICE OF MAIZE (MT)	122.00			
ADJUSTED PRICE	109.80			
	LOCAL		CCA	
	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer
Average Yield	1.30	2.10	.90	1.60
Adjusted Yield(Net)[a]	1.17	1.89	.81	1.44
Gross Benefit[b]	128.47	207.52	88.94	158.11
No. of bags/acre[c]				
CAN	.00	.00	.00	.00
20:20:0	.00	1.00	.00	1.00
S/A	.00	2.00	.00	2.00
Variable Cost				
Fertilizer Cost (K/acre)	.00	58.50	.00	58.50
Fertilizer Cost/ Ha[d]	.00	146.25	.00	146.25
Application	.00	6.25	.00	6.25
Seed	.00	.00	6.25	6.25
Total Variable Costs	.00	152.50	6.25	158.75
NET BENEFIT[e]	128.47	55.02	82.69	-.64
Return to K1.00 Invested	N/a	negative	negative	negative

Source: Farming System Research Section and Official Prices from a parastatal.

a) Average yield times discount factor of 0.90.
b) Gross benefit = net yield times adjusted price (Field price adjusted 10 percent down).
c) 1 bag =50kg.
d) The costs per acre were converted to costs per Hectare.
e) Net Benefit = Gross Benefit - total variable cost.

Note: K1.00 is approximately $0.60 (U.S.)

TABLE 4.10

Sensitivity Analysis using a Hypothetical

Maize price (K150/M.T.) and 1983-84 Fertilizer Prices

SECOND VILLAGE				
PRICE OF 50 KG OF FERTILIZER				
CAN	17.50			
20:20:0	20.50			
S/A	19.00			
FIELD PRICE OF MAIZE (MT)	150.00			
ADJUSTED PRICE	135.00			
	LOCAL		CAA	
	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer
Average Yield	1.30	2.10	.90	1.60
Adjusted Yield(Net)[a]	1.17	1.89	.81	1.44
Gross Benefit[b]	157.95	255.15	109.35	194.40
No. of bags/acre[c]				
CAN	.00	.00	.00	.00
20:20:0	.00	1.00	.00	1.00
S/A	.00	2.00	.00	2.00
Variable Cost				
Fertilizer Cost (K/acre)	.00	58.50	.00	58.50
Fertilizer Cost/ Ha[d]	.00	146.25	.00	146.25
Application	.00	6.25	.00	6.25
Seed	.00	.00	6.25	6.25
Total Variable Costs	.00	152.50	6.25	158.75
NET BENEFIT[e]	157.95	102.65	103.10	35.65
Return to K1.00 Invested	N/A	negative	negative	negative

Source: Farming System Research Section and Official Prices from a parastatal.

a) Average Yield times discount factor of 0.90.

b) Gross benefit = net yield times adjusted price (Field price adjusted 10 percent down).

c) 1 bag = 50kg.

d) The costs per acre were converted to costs per Hectare.

e) Net Benefit = Gross benefit - total variable cost.

Note: K1.00 is approximately $0.60 (U.S.)

Fertilizer Trial

The trial was designed to determine the response of nitrogen fertilizer application. In this experiment, four farmers participated, with three replications on each farm. Five levels of nitrogen were applied: 0 N; 40 N (split); 40 N all basal; 80 N (split; and 80 N (40 N + 40 N P_2O_5 basal and 40 N top dressing). The numbers are in kilograms per hectare and the source for nitrogen was Calcium Ammonium Nitrate (CAN).

The data used in the analysis are in Table 4.11a.

Statistical Analysis

Using MSTAT, the analysis of variance revealed the following results. Locations were found to be significant at the 0.001 level, indicating the locations were quite different. Nitrogen significantly affected yield at less than the 0.001 level. This means that local maize responded to added levels of nitrogen. The interaction between location and fertilizer levels was not significant at the 0.05 level. This implies there was a general response across sites. (Table 4.11b)

The significant difference due to locations called for refinement of the recommendation domain-the group of farms or farmers with similar characteristics for whom the trials were designed. This analysis suggests that a single recommendation will not be appropriate for all the farmers (locations).

TABLE 4.11a

LOCAL MAIZE FERTILIZER TRIAL, Dowa-West, Malawi
1983-84

Yield Figures In Kilograms/ Ha

	TREATMENT				
	1	2	3	4	5
LOCATION					
1)	1693	1712	2654	1259	3779
	2034	3009	1184	1912	2423
	2795	2591	2324	3909	3327
2)	590	1250	829	3460	2508
	1238	2441	1816	3664	3701
	2247	1601	3917	4326	4131
3)	934	1753	934	1455	1897
	934	1329	986	1019	3010
	264	1541	1029	1915	1373
4)	191	540	29	1457	767
	37	207	299	1093	1003
	177	383	410	1085	1273

NOTE: There are three replications on each location

Treatment 1) = zero nitrogen

Treatment 2) = 40 nitrogen split

Treatment 3) = 40 nitrogen all basal

Treatment 4) = 80 nitrogen split

Treatment 5) = 80 nitrogen 40 phosphorus

Source: Adaptive Research Section, DAR (Malawi)

TABLE 4.11b

ANALYSIS OF VARIANCE TABLE,
Local Maize Fertilizer Trial.
Dowa-West, Malawi, 1983-84

Code	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
1	Location	3	36430399.46	12143466.486	13.08	.0 01
-3	R(L)	8	7427112.38	928389.048		
4	A	4	15407907.64	3051976.909	12.13	.000
5	LA	12	7361539.36	613461.614	1.93	.067
-7	Error	32	10158770.93	317461.591		

Coefficient of Variations = 32.99%

Source: Adaptive Research Section, DAR (Malawi)

R(L) refersto error from the locations.
A refers to treatments
LA refers to the interaction between location and treatment.

Economic Analysis

An attempt was made to estimate a fertilizer response (production function) for each location, because of significant locations effects, using MSTAT, but no meaningful results were obtained. Regression results were not meaningful because there was no significant relationship between nitrogen level and yield for all locations. Part of the problem was that there were only three levels of nitrogen included in the trial - after excluding the 40 N (all basal) and the one treatment that had phosphorus included. Also, factors interacting with the treatments were not known. Due to these reasons and because of inconsistent relationships, the analysis was removed entirely and only marginal analysis was done on this data.

However, the method for estimating parameters using multiple regression from MSTAT was mastered so that this was only a problem of data. This result demonstrated that if response functions are to be estimated, the trials must be planned to include several input levels that are comparable.

Marginal Benefit Cost Analysis

For purposes of this exercise, the location effect

was assumed away (that need not be the case). The analysis was performed with Supercalc, a spreadsheet template developed by Dr. Richard Bernsten (for a description of the program see appendix II). The final calculations were done by hand. The program helped to compute all the necessary information to complete a marginal benefit cost analysis.

The initial run of the program used prices in effect during the 1983-84 season. Data used were mean yields of each of five treatments (see average yield in Table 4.12). The price of maize used was K0.122 per kilogram, although the program only prints K0.12, because of rounding off. The price of a 50 kilogram bag of 20:20:0 and CAN were K20.50 and K17.50, respectively. These bags contained 20 and 17 percent nitrogen, respectively. Fertilizer credit and transport cost were set at zero because they were not known. With all prices and parameters specified, the program calculated all information needed to estimate the marginal benefit cost ratios. Table 4.12 should be used for marginal benefit cost analysis.

All analyses had the same format. Net benefits from each treatment show that no level of fertilizer application was better than the zero level. The net benefit

le 4.12 Economic analysis of a fertilizer trial, crop: maize, variety: Local location: [illegible] West season: 1983/84 year: 1983/84

Treatment number	Fertilizer treatment (kg/ha) Nirtogen	Phosphorus	Potash	Other	Average yield (kg/ha)	Net yield (kg/ha)	Gross field benefit (K/Ha)	Variable cash costs: Fertilizer	Transport	Variable opportunity costs: Fert labor	Credit	Total variable costs (K/Ha)	Net benefits (K/Ha)	Dominant treatment (Y/N)
1	.00	.00	.00	.00	1094.50	1094.50	130.79	.00	.00	.00	.00	.00	130.79	
2	40.00	.00	.00	.00	1552.25	1552.25	185.49	82.35	.00	4.06	.00	86.41	99.08	
3	40.00	.00	.00	.00	1367.58	1367.58	163.43	82.35	.00	4.06	.00	86.41	77.01	
4	80.00	.00	.00	.00	2212.83	2212.83	264.43	164.71	.00	8.12	.00	172.82	91.61	
5	40.00	40.00	.00	.00	2432.67	2432.67	290.70	164.35	.00	7.51	.00	171.86	118.84	

Parameter Menu		Coefficient
Net yield factor:		1.00
Farm gate pri ce(K/kg):		.12
Harvest costs		
rate(kg/MD):		200.00
wage(K/MD):		.50
Tenure status		
owner	(if yes, set share at 1, l ease at K 0)	
share	crop share farmer receives (.00%)	1.00
	fertilizer costs farmer pays (.00%)	1.00
lease	(K/ha) paid by farmer	.00
Fertilizer price (K/kg):		
N(can)	.17	2.06
P(20:20:0)	.20	2.05
K20	.50	40.00
other	.00	.00
Fertilizer transport		
transport rate (K/km):		.00
distance to source(km)		5.00
Fertilizer labor costs		
days(MD/ha/100kg):		6.90
wage (K/MD):		.25
Fertilizer credit cost		
time to repay(years):		.00
interest rate(.00%):		.18

from zero level was the highest. At these prices and parameter levels, the recommendation was to use no fertilizer at all.

Sensitivity Analysis

This analysis involved changing input prices and/or the price of maize, in order to see how the marginal return to fertilizer changes.

Suppose the price of maize was increased to K0.15 per kilogram (hypothetical) while the prices of fertilizer remained at K20.50/50 kg bag for 20:20:0 and K17 50/50 kg bag for CAN. This was accomplished by changing the farm gate price from K0.122 to K0.15 in the program. With this completed the program computed all needed values for the analysis. From Table 4.13, the net benefits and total variable costs were extracted for analysis. The two dominant treatments were the zero level; and 80 kilogram of N and 40 Kilograms of P. From this, the marginal rate of return (MRR) was computed, as shown below:

where:

Net benefits for 80kg/ha of N and 40kg/ha P is 186.96,

Net Benefit for zero N is 161.44

Total variable costs for 80kg/ha N and 40kg/ha P is 171.86

Total variable cost for zero N is 0.

$$MRR = \frac{186.96 - 161.44}{171.86 - 0} = 0.148$$

TABLE 4.13

Table 4.13 – Economic analysis of a fertilizer trial, crop: maize, variety: Local location: DOwa-West season: 1983/84 year: 1983/84

Treatment number	Fertilizer treatment (kg/ha) Nitrogen	Phosphorus	Potash	Other	Average yield (kg/ha)	Net yield (kg/ha)	Gross field benefit (K/Ha)	Variable cash costs: Fertilizer	Transport	Variable opportunity costs: Fert labor	Credit	Total variable costs (K/Ha)	Net benefits (K/Ha)	Dominant treatment (Y/N)
1	.00	.00	.00	.00	1094.50	1094.50	161.44	.00	.00	.00	.00	.00	161.44	Y
2	40.00	.00	.00	.00	1552.25	1552.25	228.96	82.35	.00	4.06	.00	86.41	142.55	
3	40.00	.00	.00	.00	1367.58	1367.58	201.72	82.35	.00	4.06	.00	86.41	115.31	
4	80.00	.00	.00	.00	2212.83	2212.83	326.39	164.71	.00	8.12	.00	172.82	153.57	
5	40.00	40.00	.00	.00	2432.67	2432.67	358.82	164.35	.00	7.51	.00	171.86	186.96	Y

Parameter Menu		Coefficient
Net yield factor:		1.00
Farm gate price(K/kg):		.15
Harvest costs		
rate(kg/MD):		200.00
wage(K/MD):		.50
Tenure status		
owner	(if yes, set share at 1, lease at K 0)	
share	crop share farmer receives (.00%)	1.00
	fertilizer costs farmer pays (.00%)	1.00
lease	(K/ha) paid by farmer	.00
Fertilizer price (K/kg):		
N(can)	.17	2.06
P(20:20:0)	.20	2.05
K20	.50	40.00
other	.00	.00
Fertilizer transport		
transport rate (K/km):		.00
distance to source(km)		5.00
Fertilizer labor costs		
days(MD/ha/100kg):		6.90
wage (K/MD):		.25
Fertilizer credit cost		
time to repay(years):		.00
interest rate(.00%):		.18

This gave a return of approximately 15 percent. Taking 40 percent as a deciding point, this return was well below the acceptance level. Therefore, the zero level was still accepted as a tentative recommendation.

The old prices (1982-83) of maize and fertilizer were then used, prices that were in effect a year before these trials were conducted. Then the farm gate price was K0.11 per kilogram and 20:20:0 was K8.50 while CAN was K7.50 per 50 kilograms. (Table 4.14).

Table 4.14 shows that the three dominant treatments were zero nitrogen, 40 kilogram of nitrogen (split), and 80 kilogram of nitrogen plus 40 kilogram phosphorus per hectare. Arranging these dominant treatments in descending order the marginal rate of return (MRR) is calculated as shown below:

The MRR from zero nitrogen to 40 kilogram nitrogen per hectare is:

$$\frac{127.51 - 117.66}{39.35 - 0} = \frac{9.85}{39.35} = 0.250$$

so that MRR = 25 percent.

The MRR from 40 kilograms of nitrogen to 80 kilogram nitrogen and 40 kilogram phosphorus is:

$$\frac{184.71 - 127.51}{76.80 - 39.35} = \frac{54.20}{37.45} = 1.53$$

so that MRR = 153 percent.

ble 4.14 Economic analysis of a fertilizer trial, crop: maize, variety: Local location: DOma-West season: 1983/84 year: 1983/84

Treatment number	Fertilizer treatment (kg/ha) Nitrogen	Phosphorus	Potash	Other	Average yield (kg/ha)	Net yield (kg/ha)	Gross field benefit (K/Ha)	Variable cash costs: Fertilizer	Variable cash costs: Transport	Variable opportunity costs: Fert labor	Variable opportunity costs: Credit	Total variable costs (K/Ha)	Net benefits (K/Ha)	Dominant treatment (Y/N)
1	.00	.00	.00	.00	1094.50	1094.50	117.66	.00	.00	.00	.00	.00	117.66	Y
2	40.00	.00	.00	.00	1552.25	1552.25	166.87	35.29	.00	4.06	.00	39.35	127.51	Y
3	40.00	.00	.00	.00	1367.58	1367.58	147.02	35.29	.00	4.06	.00	39.35	107.66	
4	80.00	.00	.00	.00	2212.83	2212.83	237.88	70.59	.00	8.12	.00	78.71	159.17	
5	40.00	40.00	.00	.00	2432.67	2432.67	261.51	69.29	.00	7.51	.00	76.80	184.71	Y

Parameter Menu		Coefficient
Net yield factor:		1.00
Farm gate price(K/kg):		.11
Harvest costs		
rate(kg/MD):		200.00
wage(K/MD):		.50
Tenure status		
owner	(if yes, set share at 1, lease at K 0)	
share	crop share farmer receives (.00%)	1.00
	fertilizer costs farmer pays (.00%)	1.00
lease	(K/ha) paid by farmer	.00
Fertilizer price (K/kg):		
N(can)	.17	.88
P(20:20:0)	.20	.85
K20	.50	40.00
other	.00	.00
Fertilizer transport		
transport rate (K/km):		.00
distance to source(km)		5.00
Fertilizer labor costs		
days(MD/ha/100kg):		6.90
wage (K/MD):		.25
Fertilizer credit cost		
time to repay(years):		.00
interest rate(.00%):		.18

Given these results and the 40 percent cut-off point, the tentative recommendation per hectare would be 80 kilograms of nitrogen and 40 kilograms of phosphorus.

Now, we want to consider the case where the price of fertilizer is unchanged (1982-83 level) while the maize price is increased from K0.11 to K0.122 per kilogram. Results for this consideration are found in Table 4.15. Table 4.15 shows the dominant treatments as 0, 40, and 80 nitrogen and 40 kilogram of phosphorus per hectare. Arranging these in descending order and calculating the MRR, we have:

The MRR from zero to 40 kilogram of nitrogen per hectare is:

$$MRR = \frac{146.14 - 130.79}{39.35 - 0} = \frac{15.35}{39.35} = 0.39$$

This is almost 40 percent.

The MRR from 40 to 80 kilograms of nitrogen and 40 kilograms of phosphorus per hectare is:

$$MRR = \frac{213.90 - 146.14}{76.80 - 39.35} = \frac{67.76}{37.45} = 1.809 = 1.81$$

or a value of 181 percent.

These results indicate both the 40 kilograms nitrogen and 80 kilograms nitrogen plus 40 kilograms phosphorus per hectare treatments yielded at least a 40 percent marginal rate of return to additional investment.

ble 4.15 Economic analysis of a fertilizer trial, crop: maize, variety: Local location: DOma-West season: 1983/84 year: 1983/84

Treatment number	Fertilizer treatment (kg/ha) Nitrogen	Phosphorus	Potash	Other	Average yield (kg/ha)	Net yield (kg/ha)	Gross field benefit (K/Ha)	Variable cash costs: Fertilizer	Transport	Variable opportunity costs: Fert labor	Credit	Total variable costs (K/Ha)	Net benefits (K/Ha)	Dominant treatment (Y/N)
1	.00	.00	.00	.00	1094.50	1094.50	130.79	.00	.00	.00	.00	.00	130.79	Y
2	40.00	.00	.00	.00	1552.25	1552.25	185.49	35.29	.00	4.06	.00	39.35	146.14	Y
3	40.00	.00	.00	.00	1367.58	1367.58	163.43	35.29	.00	4.06	.00	39.35	124.07	
4	80.00	.00	.00	.00	2212.83	2212.83	264.43	70.59	.00	8.12	.00	78.71	185.73	
5	40.00	40.00	.00	.00	2432.67	2432.67	290.70	69.29	.00	7.51	.00	76.80	213.90	Y

Parameter Menu		Coefficient
Net yield factor:		1.00
Farm gate pri ce(K/kg):		.12
Harvest costs		
rate(kg/MD):		200.00
wage(K/MD):		.50
Tenure status		
owner	(if yes, set share at 1, l ease at K 0)	
share	crop share farmer receives (.00%)	1.00
	fertilizer costs farmer pays (.00%)	1.00
lease	(K/ha) paid by farmer	.00
Fertilizer price (K/kg):		
N(can)	.17	.88
P(20:20:0)	.20	.85
K20	.50	40.00
other	.00	.00
Fertilizer transport		
transport rate (K/km):		.00
distance to source(km)		5.00
Fertilizer labor costs		
days(MD/ha/100kg):		6.90
wage (K/MD):		.25
Fertilizer credit cost		
time to repay(years):		.00
interest rate(.00%):		.18

However, the marginal rate of return for the 80 kilogram of nitrogen and 40 kilogram of phosphorus was far higher than the cutoff mark of 40 percent. Consequently this treatment would be recommended at these prices of inputs and output.

Finally, the old prices (1982-83 level) of fertilizer and the hypothetical K0.15 per kilogram maize price were considered (Table 4.16). From Table 4.16, the dominant treatments were identified. The dominant treatments were the same as in the case above.

The MRR from zero nitrogen to 40 kilograms of nitrogen per hectare is:

$$\frac{189.60 - 161.44}{39.35 - 0} = \frac{28.16}{39.35} = 0.72$$

or a value of 72 percent.

The MRR from 40 kilograms to 80 kilograms of introgen and 40 kilograms of phosphorus per hectare is:

$$\frac{282.02 - 289.60}{76.80 - 39.35} = \frac{92.42}{37.45} = 2.47$$

or a value of 247 percent.

From these results, the recommendation would be 80 kilograms of nitrogen and 40 kilogram of phosphorus. Although 40 kilogram of nitrogen yielded a rate of return higher than 40 percent, it was inferior to the other dominant treatment.

4..1.6.. Economic analysis of a fertilizer trial, crop: maize, variety: Local location: DOma-West season: 1983/84 year: 1983/84

Treatment number	Fertilizer treatment (kg/ha) Nirtogen	Phosphorus	Potash	Other	Average yield (kg/ha)	Net yield (kg/ha)	Gross field benefit (K/Ha)	Variable cash costs: Fertil-zer	Transport	Variable opportunity costs: Fert labor	Credit	Total variable costs (K/Ha)	Net benefits (K/Ha)	Dominant treatment (Y/N)
1	.00	.00	.00	.00	1094.50	1094.50	161.44	.00	.00	.00	.00	.00	161.44	Y
2	40.00	.00	.00	.00	1552.25	1552.25	228.96	35.29	.00	4.06	.00	39.35	189.60	Y
3	40.00	.00	.00	.00	1367.58	1367.58	201.72	35.29	.00	4.06	.00	39.35	162.37	
4	80.00	.00	.00	.00	2212.83	2212.83	326.39	70.59	.00	8.12	.00	78.71	247.69	
5	40.00	40.00	.00	.00	2432.67	2432.67	358.82	69.29	.00	7.51	.00	76.80	282.02	Y
6														

Parameter Menu		Coefficient	
Net yield factor:		1.00	
Farm gate price(K/kg):		.15	
Harvest costs			
rate(kg/MD):		200.00	
wage(K/MD):		.50	
Tenure status			
owner share	(if yes, set share at 1, lease at K 0)		
	crop share farmer receives (.00%)	1.00	
	fertilizer costs farmer pays (.00%)	1.00	
lease	(K/ha) paid by farmer	.00	
Fertilizer price (K/kg):			
N(can)	.17	.88	
P(20:20:0)	.20	.85	
K20	.50	40.00	
other	.00	.00	
Fertilizer transport			
transport rate (K/km):		.00	
distance to source(km)		5.00	
Fertilizer labor costs			
days(MD/ha/100kg):		6.90	
wage (K/MD):		.25	
Fertilizer credit cost			
time to repay(years):		.00	
interest rate(.00%):		.18	

In general, the results were sensitive to the levels of prices used. The increase in input prices from the 1982-83 levels to the 1983-84 levels seems to be in excess of the increase in the maize price. The sensitivity analysis, on the whole, showed that the recommended treatment did not change, regardless of the prices used if we consider the zero level as a recommendation.

CHAPTER V

Summary and Conclusions

Agricultural research in Malawi, until the recent reorganization, did not take into account non-biological factors when developing recommendations for majority smallholder communities. In part, this was due to the unavailability of non-biological scientists in the Department of Agricultural Research. As a result, statistical analysis using analysis of variance was the only tool for evaluating proposed innovations. While analysis of variance evaluates the significance of biological treatment effects, statistical analysis alone is insufficient for making recommendations to farmers. Statistical analysis need complementary economic analysis.

Due to external recognition, in particular from the United States Agency for International Development, farming systems research was introduced in Malawi, bringing social scientists into the Department. Following a major reorganization of the Department, the FSR Section was reorganized into adaptive research teams.

The ARTs have the mandate to diagnose farmers' present circumstances and propose changes to improve the farmers' wellbeing. The proposed innovations are tested

on farms and results evaluated. Problems not solved by the ARTs are relegated to station-based biological scientists performing applied research. The ARTs also provide an important link with the Extension Department.

The major problem with the ARTs is that socioeconomists who are to provide socioeconomic input have basically the same training as the agronomists. This combination would likely result in inadequate diagnosis of farmers problems. Economic analysis, in particular, is weak thereby reducing the potential impact of the program..

Economic models considered for evaluation of farm data include simple benefit cost analyssis, marginal benefit cost analysis and production function analysis. These models serve as tools to evaluate the profitability of alternatives tested on farms. Other economic models, like simplified programming and linear programming, evaluate the feasibility of individually derived recommendations. In this paper simple cost benefit and marginal cost benefit analysis was used to evaluate agronomic trial results.

Statistical analyses showed treatments were highly

significant for variety and fertilizer trials that were evaluated. Using input and output price existing at the time the trials were conducted (1982-83), fertilizer application in the variety trial was profitable. However, at prices existing one year later, it was no longer profitable to use fertilizer on either the local or improved variety, despite the fact that the statistical analysis depicted highly significant effects. The above results were for one village. In the other village, however, it was not profitable to use fertilizer on either maize variety at the various prices of inputs and outputs considered.

Using marginal benefit cost analysis to evaluate the fertilizer trial demonstrated positive and acceptable returns in some cases, but not all, depending on prices chosen.

Economic analysis showed that statistical analysis alone can not be used to make extension recommendations. The alternatives may be statistically significant, but prices and other socioeconomic parameters must be considered to show how profitable the alternatives are.

APPENDIX I:The PC-CALC Spreadsheet

A spreadsheet was developed with a menu portion where all parameters in a simple benefit cost model could be changed. The yield discount factor was set at 0.9, to take into account the difference in yield obtained when the researchers perform the trials as opposed to when farmers grow the crop. Other parameters used were fertilizer prices for a 50 kilogram bag. The field price was the one at which the maize was sold locally. It was reduced by ten percent to take into account harvest costs, losses, shrinkage, etc.

The spreadsheet had a portion where average yields were entered for each treatment and village . Yields were reduced by 10 percent using the discount factor. The gross benefit was found by multiplying the adjusted yield by the adjusted price. The fertilizer cost was calculated by multiplying the number of bags per acre with the unit price. These figures were first calculated on a per acre basis. To convert the figures to per hectares, the figures were divided by 0.4. The cost of applying fertilizer was set at K6.25 per hectare. All costs were then added up to get the total variable cost.

The net benefits were calculated by subtracting the total variable costs from the gross benefit.

The rate of return per Kwacha invested was calculated by subtracting the net benefit of the zero treatment level for local maize from the net benefit of each treatment value greater than the zero treatment level; and dividing the results by the change in total variable cost.

In sensitivity analyses, prices were changed and the calculations were performed quickly.

APPENDIX II: The SUPERCALC Spreadsheet

Developed by Dr. Richard Bernsten

The spreadsheet was designed to analyze fertilizer experiments with multiple treatments.

The first part of the spreadsheet allows the user to enter levels of fertilizer and average yield from each treatment. Then the spreadsheet automatically calulates gross benefits and total variable costs for each treatment. Next to the first part is the parameter menu where all the parameters are entered. Here, changes may be made for sensitivity analysis or for changes in assumptions regarding the model. For example, one part contains information on the percent of fertilizer elements in sources used, and price per unit of the elements for the calculation of the total fertilizer cost. There is also a discount factor which takes into account differences in yield between experiments done by researchers and what farmers are expected to obtain when they adopt innovations. In the analysis presented in this paper, this option was not used because very little information was available about the experiments. Other parameters include labor, credit, transport costs, and share cropping proportions according to tenure arrangements. Only

labor cost were included in this analysis.

To select dominant treatments for marginal rate of return calculations, visual inspection of net benefits and total variable costs on a graph is normally done. However, dominant treatments were selected without a graph, with calculations completed by hand. Otherwise, the spreadsheet then selects the treatments from the first part. Using the data management command, the dominant treatments are arranged in descending order according to net benefits. These dominant treatments are then extracted into another table where calculations for the marginal rate of return are performed.

BIBLIOGRAPHY

Adaptive Research Section. 1984. Progress Report for the Adaptive Research Programme, August 1983-April 1984. Unpublished Manuscript.

Adaptive Research Section. 1983. The Adaptive Research Programme in Malawi, 1985. Unpublished Manuscript.

Bernsten, R. H. 1980. Prescreening Alternative Componet Technologies To Identify Probable Constraints to Farmer Adoption. Paper prepared for The Cropping Systems Economic Training Program, Bogor, Indonesia, IRRI Cooperative Program.

Bernsten, R. H. 1985. Mission Report, Department of Agricultural Economics. Michigan State University, East Lansing, Michigan, 1979. Unplublished Manuscript.

Collinson, Michael. 1979. Understanding Small Farmers. Paper given at conference on Rapid Rural Appraisal, 4-7 December, 1979, IDS, University of Sussex, Brighton, U.K.

Collinson, Michael. 1980. A Farming Systems Contribution to Improved Relevancy in Agricultural Research: Concepts and Procedures and Their Promotion by CIMMYT in Eastern Africa, Nairobi: CIMMYT

Department of Agricultural Research. 1983a. Malawi Agricultural Research Strategy Plan prepared with the assistance of IADS Operations, Inc. Unpublished manuscript.

Department of Agricultural Research. 1983b. Research - Extension Linkages inthe Ministry of Agriculture Malawi. A Discussion Paper for tneir Institutionalization. Unpublished Manuscript.

Dillon, John I., and J. Brian Hardaker. 1980. Farm Management Research for Small Farmer Development, Rome Food and Agriculture Organization of the United Nations.

Farrington, J. 1975. Farm Surveys in Malawi. The Collection and Analysis of Labour data. University of Reading Department of Agricultural Economics and Management. Development Study No. 16.

Gilbert, E. H., D. W. Norman and F. E. Winch. 1980. Farming Systems Research: A Critical Appraisal. Rural Development Paper no. 6, Michigan State University, Department of Agricultural Economics.

Hansen, Art. 1981. Farming Systems Research: Theory and Practice in Malawi. Unpublished Manuscript.

Hansen, Art, Emmanuel E. Mwango and Benson S. C. Phiri. 1982. Farming System Research in Phalombe Project Malawi. Another Approach to Smallholder Research and Development. Unpublished Paper.

Harrington, Larry W. 1980. Farmer Assessment of Maize. Recommendations in Northern Veracruz State, Mexico. Unpublished Ph.D. thesis, Michigan State University, East Lansing, Michigan.

Harsh, B. Stephen, Larry J. Connor and Gerald D. Schwab. 1981. Managing the Farm Business. Englewood Cliffs, New Jersey: Prentice-Hall.

Heady, Earl and W. Chandler. 1958. Linear Programming Methods. Ames, Iowa: Iowa State College Press.

Heady, Earl O. and John Dillon. 1961. Agricultural Production Functions. Ames, Iowa: The Iowa State University Press.

Hilderbrand, Peter. E. 1979. Summary of the Sondeo Methodology Used by ICTA. Guatemala: Instituto de Ciencia y Tecnologia Agricola.

International Agricultural Development Service (IADS) 1983. Setting Research Priorities: Malawi as A Case Study. New York: IADS.

International Service for National Agricultural Research (ISNAR). 1982. A Review of Agricultural Research System in Malawi. The Hague, Netherlands.

Malawi Government National Statistical Office. 1980. Malawi Statistical Yearbook. Zomba: The Government Printer.

Malawi Government National Statistical Office. 1981. Malawi Stitistical Yearbook. Zomba: The Government Printer.

Nyirenda, F. M. 1984. Adaptive Research Programme in Malawi. A paper presented at the 1984 Agricultural Development Departmental Conference held at Club Makokola, Mangochi, August 27-31.

Perrin, K. Richard, Donald L. Winkelmann, Edgardo R. Moscardi and Jock R. Anderson. 1976. From Agronomic Data to Farmer Recommendations: An Economics Training Manual El Baton, Mexico. Centro Internationaal de Mejoramiento de Maiz Y Trigo (CIMMYT)

Phiri, Benson. 1984. Analysis of Data From Phalombe Rural Development Project (Blantyre Agricultural Development Division) Malawi, 1981/82. A Class Project for a Course: Computers in Agriculture, University of Florida. Unpublished Manuscript.

Shanner, W. W., P. F. Philipp and W. R. Schnehl. 1981. Farming Systems Research and Development: Guidelines for Developing Countries, Boulder, Colorado: Westview Press.

Simmonds, Norman W. 1985. Farming Systems Research: A Review. Washington DC: World Bank Technical Paper Number 43.

Sonka, Steven. 1980. Computers in Farming: Selection and Use. New York: McGraw-Hill Book Company.

The African Business. 1984. "The Great Grain Success Story." Number 73

Upton, Martin. 1973 Farm Management in Africa; The Principles of Production and Planning. London: Oxford University Press.

Weathers, Clyde R. 1964. Simplified Programming--- a tood in Farm Planning. Raleigh, North Carolina: North Carolina Agricultural Extension Service.