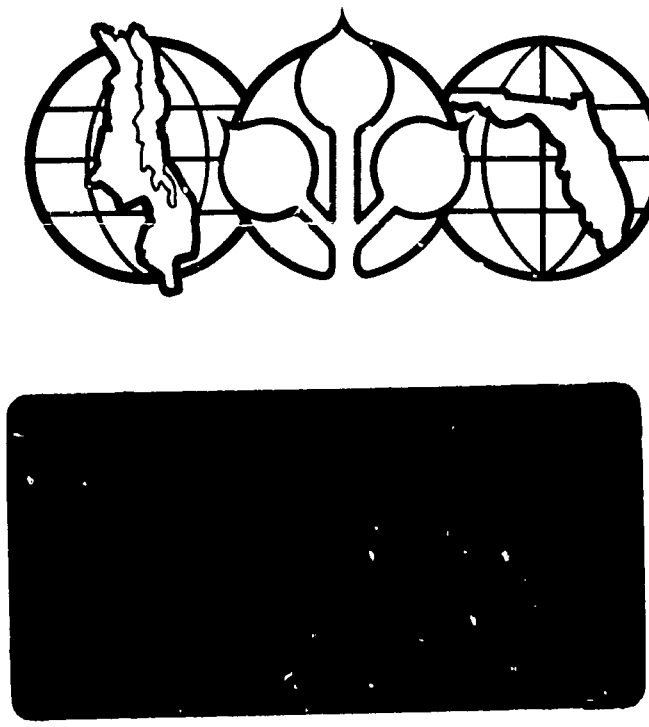

Malawi Agricultural Research Project

Center for Tropical Agriculture
International Programs
Institute of Food and Agricultural Sciences
University of Florida

The Department of Agricultural Research
Ministry of Agriculture, Malawi

The U.S. Agency for International
Development

PD-AAK 672
ISN 41079

QUARTERLY REPORT

April, May and June

1982

Project No. AFR 06 612-0202

Contract No. AID/afr-C-1653 (Malawi)

MP 8
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I. INTRODUCTION

The University of Florida technical assistance team is in Malawi as part of the Malawi Agricultural Research Project, AFR C[illegible] 612-0202, the purpose of which is to strengthen the Department of Agricultural Research of the Ministry of Agriculture. This project is funded by the United States Agency for International Development (USAID) and the Malawi Government. The University of Florida is administering the project as the Title XII contracting institution.

This is the eighth quarterly report and covers the first quarter of the 1982-83 Malawi fiscal year, April - June 1982.

II. HIGHLIGHTS

Participant training continued to be a major project objective. At the end of the quarter, 17 Malawi Professional Officers remained in the U.S. pursuing M.S. and Ph. D. training and one participant trainee had returned to Malawi during the quarter due to inadequate academic performance. One participant trainee and his advisor visited Malawi during the quarter to collect data for the trainee's thesis.

In-service training activities during the quarter included supervising Malawi professional officers in preparation of papers which were to be presented at the "International Conference on Development in Malawi in the 1980s" at Chancellor College in July.

Two short-term TDY consultants taught courses on "Irish Potato Culture" and "Fruit Production and Management Practices" at the Bvumbwe Agricultural Research Station.

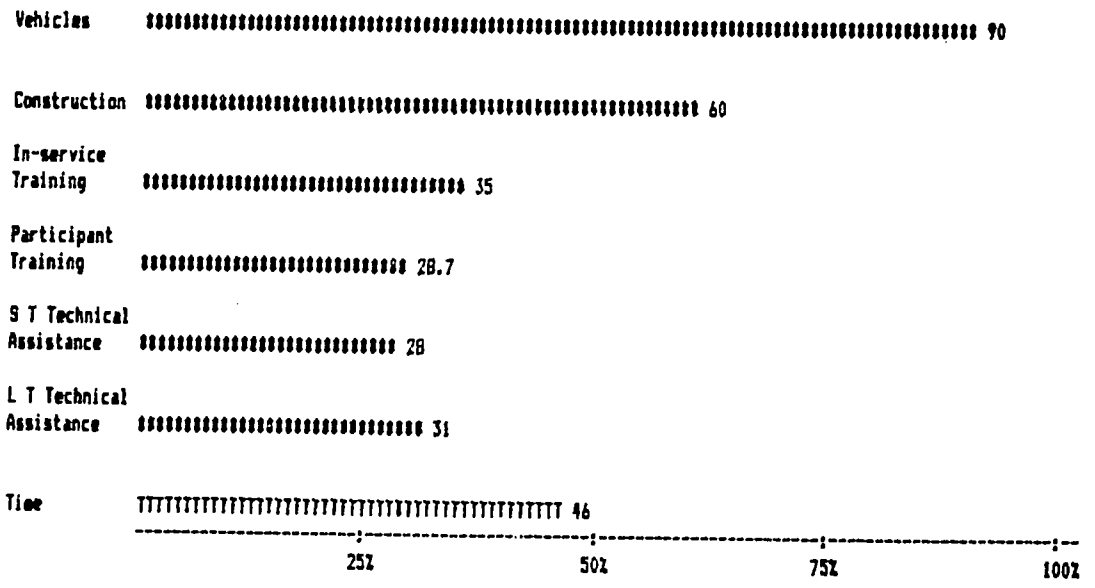
Six long term technical assistants remained in Malawi at the end of the quarter. Dr. Ian McClean and his family departed Malawi on 31 May 1982.

Purchase of project commodities continued. Four Nissan pickup trucks were acquired, one was assigned to Makoka and three to Chitedze. Equipment for the "Feed and Forage Evaluation Laboratory" began to arrive in Malawi during the quarter.

Since strengthening of research programs is a major project objective, all team members continued their activities in assisting Malawian Professional Officers in planning and conducting research activities. Research plots were harvested during the quarter and data were collected and the analysis process was begun, so that results will be available for use in planning next season's research trials, and for making recommendations to the extension service.

Field days were held at most research stations during the quarter, with team members attending and assisting with several of them.

A summary of the project inputs through June 30, 1982 is given in Figure 1.



ST = short term
LT = long term

Figure 1. Malawi Agricultural Research Project, Summary of Inputs to June 30, 1982.

III. TRAINING

A. PARTICIPANT TRAINING

The training of Malawi research officers continues as a primary goal of the Malawi Agricultural Research Project. As of June 30, 1982, seventeen Participant Trainees remained in the U.S. studying for M.S. and Ph.D. Degrees (11 Ph.D. and 6 M.S.). One participant trainee returned to Malawi in June after being terminated without receiving a degree because of unsatisfactory performance. At the end of the quarter 28.7 percent of the person months allocated for participant training had been used. (See Table 1).

Table 1

PARTICIPANT TRAINING QUARTERLY REPORT
April 1 to June 30, 1982

Name	Training	Degree Program	Station	Departure	Months Accumulated	Due Back	Funded To	Degree
Chapola G.M.	Plant Pathology	Ph.D.	Bvumbwe	Dec 27 '80	18	Apr 84	Jun 84	
Chigwe C.F.B.	Sorghum Breeding	Ph.D.	Makoka	Dec 28 '81	6	Dec 84	Jun 85	
Chikwana R.	Agricultural Economics	M.S.	Chitedze	Dec 26 '80	18	Dec 82	Jun 83	
Chilembwe E.H.	Fruit Crops	M.S.	Bvumbwe	Dec 27 '80	18	Jun 83	Jun 83	
Chipala E.E.	Soybean Breeding	Ph.D.	Chitedze	Dec 26 '80	18	Dec 83	Jun 84	
Dzowela B.H.	Pasture Agronomy	Ph.D.	Chitedze	Dec 26 '80	18	Jun 84	Jun 84	
Gondwe W.T.	Vegetable Crops	M.S.	Bvumbwe	Dec 28 '81	6	Dec 83	Jun 84	
Khonje D.J.	Soil Microbiology	Ph.D.	Chitedze	Dec 28 '81	6	Dec 84	Jun 85	
Kisyombe F.	Statistics	M.S.	Makoka	Dec 27 '80	17	Jun 82	*Terminated	
Mkamanga G.Y.	Crop Physiology	Ph.D.	Chitedze	Dec 26 '80	18	Jun 84	Jun 84	
Mtambo P.J.	Seed Technology	B.S.	Chitedze	Dec 28 '81	6	Dec 83	Jun 85	
Munthali J.T.K.	Animal Nutrition	Ph.D.	Chitedze	Dec 26 '80	18	Dec 83	Jun 84	
Mzembe C.P.	Irrigation Agronomy	M.S.	Kasinthula	Dec 27 '80	18	Jun 83	Jun 84	
Ngwira L.D.H.	Maize Agronomy	M.S.	Chitedze	Dec 28 '81	6	May 84	Jun 84	
Ntokotha E.M.	Soil Survey	Ph.D.	Lilongwe	Dec 26 '80	18	Jun 84	Jun 84	
Saka A.L.	Soil Physics	Ph.D.	Chitedze	Dec 27 '80	18	Dec 83	Jun 84	
Sibale P.K.	Groundnut Breeding	Ph.D.	Chitedze	Dec 26 '82	18	Jun 84	Jun 84	
Zambezi B.T.	Maize Breeding	M.S.	Chitedze	Jun 4 '81	13	Dec 83	Dec 84	
Total					258			

* Terminated without Degree in May 1982

B. IN-SERVICE TRAINING

1. Agricultural Economics

Miss Nthakomwa was supervised in the preparation of two papers. One compared the economic viability of two alternative technologies using a similar study completed earlier jointly, as an example. The main analytical tools of analysis were internal rate and net present value. The other paper will be presented at the "International Conference on Development in Malawi in the 1980s" at Chancellor College in July. This experience will be useful later in her career.

Requests were submitted to DAR, GOM for out-of-country travel to two International Research Stations for Miss Nthakomwa, but they were disapproved because she will be going to the U.S. for participant training shortly.

2. Farming Systems.

In-service training for the two professional staff members continued with their learning how to survey gardens, interview people, collect and record data, and how to harvest and evaluate trials. The staff travelled 3044 miles during the quarter, much of this in the Lilongwe area interviewing and later collecting yield samples.

During June the staff also worked at writing a report on work in Phalombe, with each person contributing to the report. This report will be presented by the Malawian staff at the "International Conference on Development in Malawi in the 1980s" at Chancellor College in July.

3. Plant Breeding

Dr. Mwandemere, OIC, Chitedze ARS, traveled to Zimbabwe and Kenya as in-service training to: (1) observe wheat production practices in these countries; (2) identify improved production practices that might benefit Malawi; (3) establish working relations with wheat researchers in these countries; and (4) identify high yielding wheat varieties for rainfed and irrigated production to include in Malawi's wheat research program.

IV. RESEARCH

A. Agricultural Economics

On this project Agricultural Economics views research itself as a secondary objective; the primary objective being to develop a capacity to do economic research in the Department of Agricultural Research. Research is conducted as a tool for demonstrating how it is done. While topical problems are chosen where possible, this is considered secondary to the development of the research capacity. In the conduct of all research, a multidisciplinary approach is taken and an effort made to integrate economic considerations into the design, execution and data analysis of agronomic research.

Activities which contributed to meeting the project objectives were as follows:

1. Worked with the Groundnut Pathologist on the economics of fungicides. The results were discussed with a representative from Shell Chemicals.

2. Prepared an informal paper for the Officer-in-Charge, Chitedze, regarding expected supply responses to changes in the price of rice.

3. Did some preliminary traveling and investigations regarding wheat production in Malawi.

4. The maize-fertilizer response trials at Chitedze were harvested and analysis begun but, due to lodging damage and high initial fertility of the soil, the data were expected to be of marginal interest.

5. As part of the price responsiveness survey in the Mchinji area it was necessary to calculate the area of irregularly shaped farmers fields from range and bearing data. A program was written in BASIC for the HP-85 computer to accomplish this. The mathematics were supplied by LADD. Several other sections at the Chitedze station, including Farming Systems, will also find this program useful.

6. Began preparation of a paper "A Review of the Effects of Food Price Policies". This is a general paper based on simple demand/supply relationships and a review of the literature. It will be presented at the "Internatonal Conference on Development in Malawi in the 1980's" to be held at Chancellor College 12-24 July 1982.

B. Crop Physiology

Activities in the Groundnut Section which were aimed at strengthening the research program centered on development and initiation of groundnut crop physiology work, which heretofore had not been part of the research program. Activities during the quarter were:

1. KOPY Experiment. Harvest of this experient was completed on June 14, 1982. At day 143 there was a slight indication of increased pod numbers for Chalimbana with the KYLAR treatments. We expected this response, however, Mani Pintar also showed the same trend which was not expected.

2. POPY-81 Experiment. Completed harvests of POPY-81 on May 11, 1982. Yields of Mani Pintar were 6.9 tons per hectare, CO2 7.8 and Chalimbana 4.4. The yield of 7.8 t/ha is a record yield for Malawi. Simulation modeling will be used to assist in determining the reasons for this year's high yields.

C. Farming Systems

Two major objectives of the project are to establish a farming systems research program and a research/extension liaison program. The farming systems program completed its first year of adaptive on-farm trials during the quarter, and that progrm has provided an organizational framework for research and extension staff to work together. In the three areas in the country where the program has progressed from surveys to on-farm trials (in Liwonde the A.D.D. provides strong leadership), research/extention liaison is much stronger than it was before.

1. Phalombe Trials

May and June were harvest months. The maize trials in Lilongwe and at Chitedze Research Station were harvested by research, while another procedure was used in Phalombe. An important aspect of the Phalombe trial is small holder participation. Villagers took part in planning; trials were on farmers' fields and largely managed by farmers; and farmers helped harvest and evaluate the trials.

Preliminary conclusions from the first year's work in Phalombe were formulated during June. The Maize Breeder and Chief of Party were extremely helpful in analyzing the data. Highlights were:

a. both varieties (CCA composite and "local") doubled yields with fertilizer.

b. except for the poorest yields, fertilizer application was profitable to both maizes.

c. for most farmers "local" maize yielded the same or better than the composite, with or without fertilizer; and

d. for the farmers with highest yields, with or without fertilizer, the composite yielded more than "local" maize.

Preliminary conclusions after this single year were that research and extension should include "local" in their recommendations, i.e., the focus should be on maize producton rather than on only the improved varieties, and that recommendations may differ for different classes of farmers, i.e., improved varieties may be recommended for farmers with high yields (higher management?) whereas fertilizer may be recommended for all varieties under all

but the worst conditions.

2. LRDP Longitudinal Survey

Work on the LRDP longitudinal survey intensified. The Women in Agricultural Development Project became a partner in this research, and its staff worked closely with the Farming Systems staff. 130 households were traced and interviewed. These 130 contain people from the original 114 households studied in 1969/70. Another 140 households were identified that also contain people from the original 114, but these other 140 were not completely traced and identified. Thus with divorces, remarriages and maturation of children, the original 114 households became 270 in 12 years.

Only a very few of the 114 were untraceable because their names were unknown today or because all had emigrated from LRDP. This shows that the procedure for conducting longitudinal studies in Malawi has promise, and opportunities in other projects may be investigated. Preliminary interviewing collected basic demographic and educational data as well as indicators on maize production. In addition to this, maize yield samples were collected from a subsample of the 130 households. During the next quarter, a larger survey will be conducted.

D. Livestock

Major objectives of the project which were addressed by the Livestock Section during the quarter were (1) development of long range plans for livestock research, (2) strengthening of research programs in selected livestock areas, relevant to smallholders (3) procurement of research equipment and (4) determination of pasture productivity in terms of animal performance.

Work continued during the quarter on long range planning and implemention of various livestock research projects. Implementation of the Sahiwal crossbreeding project was delayed due to the inability of the Department of Animal Health and Industry to supply liquid nitrogen for semen storage. Major activities were as follows:

1. Dairy Cattle Research. Implemented the "Calcium and Phosphorous Supplementation of Dairy Cattle" trial at Lunyangwa Research Station. One half of the herd will continue to receive only salt as a source of minerals and the other half will receive salt and mono-calcium phosphate in a ratio of 1:2.

2. Cattle Crossbreeding. Reviewed the beef cattle crossbreeding project at Chitala. The project is designed to obtain comparative data on Malawi Zebu vs Malawi Zebu X Brahman vs Malawi Zebu X Friesian cattle. The cattle were in good condition, but the project objectives are not being attained for various reasons. Steps were taken to rectify the problems. Plans were made to continue land clearing for establishment of additional pastures to maximize the use of available land and increase the number of livestock at the station. A Brahman bull was also obtained for the project.

3. Pasture Experiment. Work continued during the quarter on physical facilities for the pasture experiment. Installation of water lines was completed and work was begun on building of fences using creosoted posts obtained from Mazamba Sawmill. This project is a joint venture of the Livestock and Pasture Sections.

4. Apple II Computer. Timely analysis of research data and release of results are necessary to strengthen the overall research program and to improve the liaison between research and extension.

The computer which was purchased for the Livestock Section arrived in late May and was used extensively during June by the Farming Systems Section. Assistance was provided them in analyzing data from the past cropping season. The purchased statistical programs were determined not to be satisfactory; it was concluded that we would have to write and/or adapt programs for the needs of the Department of Research. Work was also started on programming a beef cattle record keeping system.

5. Feed and Forage Evaluation Laboratory. The first shipment of equipment for this laboratory was received in late April. All equipment and supplies for the laboratory are now on order.

6. Malawi Zebu Program. Began a review of the various research stations in order to determine the feasability of moving the beef cattle research herd from Dzalanyama Ranch to another location. Nearly one-half of the research paddocks at Dzalanyama Ranch have already been taken over by the Wood Energy Project, and the situation is becoming critical, with inadequate land available to maintain the herd of approximately 1,000 head.

E. Pastures

During the quarter, research activities in the pasture section were directed toward establishment of the capability to determine pasture productivity in terms of animal performance, a major project objective and strengthening of the on-going research program. Major activities which contributed progress toward these objectives were as follows:

1. Work continued on collection of data from the experimental forage plots.

2. Weeded all new plots and pastures and roughed blocks of Buffel grass for seed purity.

3. Progress continued on establishment of the grazing trial. During the quarter, all plots were weeded and silage was harvested to remove the first years growth. Work continued on construction of fences, water lines and other physical facilities. This project is a cooperative project between the Livestock and Pastures Sections.

4. Harvested leucaena leaf for use in livestock experiments and cooperated with Farm Machinery Section and National Seed Company in pelleting leucaena leaf for exploratory export.

5. Harvested legume and grass seed from nursery plots for extension of forage varieties to other Malawi locations.

6. Extended the Cynodon collection with material obtained from Estcourt Research Station, Natal, South Africa.

F. Plant Breeding

The following were accomplished to (1) define the major ecological zones in terms of maize production, (2) establish working relations with International Research Centers in neighboring countries, (3) provide agronomic advice to non-agriculturalists involved in agricultural work, (4) review past wheat research to establish research priorities, (5) update technical publicaions pertaining to maize, (6) establish new research trials aimed at improving soil fertility, and (7) fulfill the duties of the Head of the Maize Breeding Section.

Specific activities were as follows:

1. Harvested maize breeding trials at Chitedze and Ngabu ARS.

2. Arranged winter nursery requirements for seed increases needed for the 1982/83 trials.

3. Consolidated the maize agronomy research data for the preceeding five years to assist a short-term technical assistant who is coming to Malawi to advise the Maize Agronomy Section.

4. Gave advice to the Farming Systems Section on harvesting methods and agronomic data collection.

5. Developed an in-service training proposal for Dr. Mwandemere, OIC, Chitedze ARS, to visit wheat research centers in Zimbabwe and Kenya.

6. Updated the portion of the Malawi Handbook pertaining to Maize Breeding.

7. Began the statistical analysis of the 1981/82 maize breeding trials.

8. Reviewed and critiqued "Wheat Production in Malawi: Potential and Research Requirements." This report had been prepared by a consultant from Kenya.

9. Provided agronomic and statistical advice to the Women in Agriculture Project.

10. Prepared a proposal for collaborative research between the University of Florida and the Department of Agricultural Research, GOM, on the use of forage legumes as an inorganic nitrogen source.

11. Reviewed and critiqued the draft of the 1982 Wheat Research Project for Malawi.

12. At the request of the Chief Agricultural Research Officer, developed an itinerary and schedule for an FAO visitor to Malawi.

V. TRAVEL AND MEETINGS

USAID purchased vehicles continued to receive extensive use by the technical assistance team and by the Malawi staff in support of project activities. Table 2 summarizes the vehicle mileage for the current quarter and for the project to date.

Table 2

USAID Project Vehicle Miles Driven to June 30, 1982

Vehicle	Location	Apr-May-June	Mileage to June 30, 1982
Peugeot			
542D	Chitedze	5,622	27,892
715D	Bvumbwe	5,500	28,810*
716D	Chitedze	4,774	25,574
754D	Chitedze	4,920	24,840
Land Rover			
653D	Kasinthula	7,910	46,419
689D	Lunyangwa	4,500	27,570*
690D	Chitedze	7,240	38,710
691D	Makanga	6,500	40,888*
692D	Chitedze	5,159	35,636
694D	Bvumbwe	3,700	27,011*
Nissan			
474E	Chitedze/Mbawa	5,000	5,000*
483E	Chitedze	3,275	3,275
484E	Chitedze	5,250	5,250
485E	Chitedze	6,281	6,281
		---	---
	Total	70,631	343,156

*Estimated

The vehicle mileage traveled during the quarter by the technical assistance team was : Gray 1,313; Hansen 1,575; Hodges 525; McCloud 3,190; Pasley 355; and Pervis 663 for a total of 7,621 miles or 10.8% of the 70,631 total miles driven by the USAID vehicles. In addition, 15 USAID purchased motorcycles were in use by Malawian staff at various stations throughout the Department of Research.

Team members reported the following travel and meetings:

A. Gray

April 2 - Represented the UF/USAID team at the Chitala Research Station Field Day.

April 8 - Conference with Dr. Elwood, Head, Central Veterinary Laboratory, to complete USAID questionaire on African Swine Fever.

April 15 - Conference with ISNAR group on livestock research priorities.

April 20 - Accompanied Dr. George Wellington and Mr. Z. M. Nyiira, ISNAR, to Dzalanyama Ranch to observe Livestock Research actitities.

April 26 - Represented the UF/USAID team at the Mbawa Research Station Field Day.

May 4-6 - Visited Lunyangwa Research Station to implement the "Calcium and Phosphorous Supplementation of Dairy Cattle" trial and visited the Choma Livestock Multiplication Center.

May 7 - Conference with Dr. J. T. Legg and Dr. H. Mwandemere to discuss the proposed manpower needs for the Livestock and Pasture Sections. Two new Professional Officer positions were established for livestock in dairy production and physiology of reproduction. Two technical assistant positions were established for pastures. Two technical officer positions were established for livestock, a laboratory technician for the "Feed and Forage Evaluation Laboratory" and a computer operator.

June 2 - Dzalanyama Ranch to confer wih Mr. Kasowanjete on livestock research plans.

June 9 - Chitala Research Station with Mr. Kasowanjete and Mr. Mtukuso to review the cattle crossbreeding project.

June 21 - Conference with representatives of Grain and Milling and Department of Animal Health and Industry, concerning development of a better working relationship between those concerned.

B. Hansen

Dr. Hansen signed for 1575 miles in MG692D Land Rover and MG716D Peugeot, which included one week in Phalombe in May Harvesting trials and many days in the Lilongwe project. He also met with the ISNAR team studying the DAR (in particular with Dr. Elon Gilbert), with a USAID team assessing Malawi

for an upcoming agricultural extension and training project and with the Acting Officer-in-Charge, Agro-Economic Surveys, concerning a revised work plan for that agency.

C. Hodges

1. In Zimbabwe, observed pasture research areas and Cynodon nurseries at Henderson Research Station, Mazoe, forage plots at Grasslands Research Station Marandellas, and livestock and forage at Makoholi Research Station, Fort Victoria.

2. Trip to Dzalanyama Ranch to observe forage legume blocks in planted grass area and in wooded pasture.

D. McCloud

1. Dr. McCloud traveled to Ibadan, Nigeria and presented a paper at the Third African Bureau Agricultural and Rural Development Workshop on "Crop Yield Dynamics."

2. Total travel by Dr. McCloud during the quarter was 3,190 miles by Peugeot, two air trips to Bvumbwe and one to Ibadan, Nigeria.

E. Pasley

1. Met with Dr. Kim from IITA to discuss the use of maize streak resistant germplasm developed by IITA in the Malawi Maize Breeding Program.

2. Traveled to Mchinji and Mzuzu to assess potential of the two areas for increased wheat production.

3. Met with an FAO representative to discuss the Malawi Maize Breeding Program.

4. Met with a team from the Federal Republic of Germany to discuss maize production in Malawi.

5. Traveled to Ngabu ARS with Dr. Gelaw of CIMMYT to harvest maize trails.

6. Traveled to Bvumbwe ARS to introduce Dr. Arnold, short-term technical consultant, and to arrange his schedule with the OIC and staff of Bvumbwe.

7. Traveled to Bembeke and Tsangano to inspect wheat trials.

8. Attended the 26th Seed Technology Working Party Meeting as a representative of Maize Breeding.

9. Attended a budget and allocation of funds meeting, MA/GOM, as a representative of UF/USAID.

10. Met with the Chief Agricultural Development Officer to discuss the need for short-season maize varieties.

11. Met with the Officer-in-Charge, Kasinthula ARS, to

discuss the potential of short-season maize varieties under irrigation as a winter crop.

12. Traveled to Zimbabwe and Kenya with Dr. H. Mwandamere, OIC Chitedze, to observe wheat production practices, to discuss wheat research and to identify varieties that might be adapted to Malawi.

13. Met with representative from the Central African Bank to discuss maize varieties and production practices in the Mbawa area.

14. Met with a representative from the Regional Food Security Program to discuss maize breeding and the UF/USAID,MA project.

15. Met with a representative of Pioneer Ltd. (RSA), a private seed company, to discuss the need for financial assistance to conduct Pioneer maize trials in Malawi.

F. Pervis

April 8 - Met with a USAID team from Maryland which was involved in the preparation of an extension project proposal.

April - Had several discussions with Mr Richard Bolt regarding the development and integration of research and budgeting in DAR.

April 26 - Visited Estate 68 with Drs. McCloud, Pasley and Mwandemere to explore the possibility of growing wheat on small holdings.

April 30 - Visited Viphya area with Drs. Pasley and Mwandemere to examine wheat growing at higher altitudes (6000 ft) under irrigation.

April 15 - Met with a group from ISNAR concerning Agricultural Research in Malawi.

May 15 - Met informally with Dr. Hunt Davis, Director of African Studies at the University of Florida.

May - Met with the Computer Society of Malawi

June 15 - Met with P.I. Petricevic from F.A.O., who is interested in methods of calculating areas of irregular fields.

June - Ministry meeting to decide the future of the Unit Farms in Malawi.

VI. SHORT-TERM TECHNICAL ASSISTANCE

Three TDY technical assistants came to Malawi during the quarter. Their assistance was required to give expert support to the technical assistance team in disciplines of potato culture and fruit crop production and management.

A. Dr. D. R. Hensel.

Dr. Hensel, Director, Hastings Agricultural Research Center, University of Florida, arrived in Malawi on 18 April 1982 and worked for two weeks at the Bvumbwe Agricultural Research Station. The purpose of his trip was: (1) to assess the potato situation in Malawi and make recommendations on all aspects of potato seed production, production for sale, and post-harvest storage, (2) to teach a one week intensive course at the Bvumbwe Research Station on Potato poduction and post harvest storage, and (3) consult with Ministry of Agriculture personnel on the establishment of a seed potato production unit.

B. Dr. C. E. Arnold.

Dr. Arnold, Professor of Horticulture, University of Florida, was in Malawi from 10-21 May 1982 to provide technical assistance in fruit production. He worked at the Bvumbwe Agricultural Research Station and visited several other horticultural sites during his stay. He taught a course in Fruit Crop Production and Management at Bvumbwe from 18-21 May 1982.

C. Dr. V. W. Carlisle.

Dr. Carlisle, Professor of Soil Science at the University of Florida was in Malawi for one month, beginning 24 June 1982, and his graduate student, Mr. Enoc Ntokotha was here for six weeks beginning on the same date. While in Malawi, they (1) investigated the feasibility of conducting a portion of Mr. Ntokotha's research for his dissertation in Malawi, (2) conducted field investigations to determine characteristics and classification of representative soils for Mr. Ntokotha's research and (3) made morphological field descriptions of various soils and took soil samples for laboratory analysis.

VII. ADMINSTRATION

Adminstrative duties consumed a major part of the Chief-of-Party's time. Some of the many activities are listed below:

1. Prepared a memo on the USAID vehicle usage showing a total mileage of 62,738 miles, of which 23.3% was by the UF/USAID technical assistance team.

2. Prepared a memo recommending the third vehicle purchase of one Landrover and five motorcycles.

3. Completed and sent to UF the computerization of the Agricultural Research Ledger through March 31, 1982.

4. Met with Maida, Hensel and the Horticultural staff at Bvumbwe to arrange a program for Hensel's TDY.

5. Delivered a HP-85 computer to Makoka and instructed the biometrics staff in its operation.

6. Prepared a TDY request for Arnold and submitted it to the Ministry and USAID.

7. Allocated funds to Chitala, Kasinthula and Mbawa for research according to their work plans.

8. Prepared a request to the Ministry and USAID for McCloud to attend the Third African Bureau Workshop to be held at IITA, Ibadan, Nigeria on May 10-13, 1982.

9. Sent forward a request by Pasley on his R/R and travel to IITA and CIMMYT in July.

10. Met with the ISNAR group to explain the Malawi Agricultural Research project.

11. Met with the Extension pre-project team to explain research-extension liaison in the Malawi Agricultural Research Project.

12. Prepared a TDY request for Carlisle and Ntokotha to come to Malawi, and submitted it to USAID and the Ministry.

13. Sent forward the In-Service training proposal for Mwandamere and Pasley for their trip to Kenya and Zimbabwe to observe wheat production.

14. Prepared a TDY request for Rao and Saka to come to Malawi, and submitted it to USAID and the Ministry.

15. Met with CARO to finalize the allocation of Professional Officers, Technical Officers and Technical Assistant positions on the Agricultural Research Project, and to request that the necessary additional positions be established by the Malawi Government.

16. Took delivery of four Nissan 4-wheel drive pickups.

17. At the request of USAID, prepared a termination notice for Dr. McLean. The McLean family left Malawi on May 31, 1982.

18. At the Ministry's request, prepared cost estimates for the Securicor services and the utilities for the technical assistance team at Chitedze.

19. Prepared a request to USAID for medical evacuation for Dr. A. Spring.

20. Prepared a request to USAID for R/R leave for Dr. A. Hansen.

21. Based on the GRE scores, recommended Participant Trainees for 1982 to CARD.

22. Submitted a request to USAID recommending two Horticulturalists to replace Dr. McLean at Bvumbwe.

23. Attended a large computer show in South Africa, and purchased some computer supplies that we were unable to get shipped from Florida.

24. At the June team meeting, delegated the following responsibilities to team members:

a. Project Budgets - D. W. Pervis to plan, with team inputs, and develop within the project paper, guidelines for 1982-83 and 1983-84 budget years for submission to MG and USAID.

b. Research Equipment - R. C. Gray to compile, with team inputs, the equipment and supplies needed for 1982-83 and 1983-84; to prepare requisitions to purchase and to verify delivery to Malawi. The equipment and supply lists will be submitted to MG and USAID for approval.

c. In-service Training - Art Hansen to plan, with team inputs, the professional officer, technical officer and technical assistant in-service training, including extension training courses.

d. Participant Training - E. M. Hodges, with team input, develop recommedations for potential trainees to take the GRE and TOEFL examinations and nominate participant trainees to the Ministry and USAID.

e. Program Plans - S. F. Pasley, compile, with team inputs, the work plans for the team; and develop with team inputs, an overall program for the project.

VIII. Financial

Table 3 shows transactions from the University of Florida Local Account for the period 1 April 1982 through 30 June 1982, while Table 4 summarizes the expenditures by program for the quarter and for the project to date.

Table 3

Transactions-University of Florida-IFAS Local Account April, May, June 1982.

Date	Details	MK	MK
April			
1	Balance brought forward		42,608.03
1	O.H. Jere Reimb. interview on Economics	5.00	
1	V.F. Msiska Reimb. Econ. Interview	5.00	
1	G.I. Msiska Reimb. Econ.	10.00	
1	C.D. Phiri Reimb. Econ. Interview	5.00	
2	Dr. Anita Spring Medical Evacuation	15.41	
6	Dr. I.B. McLean travel reimb.	426.43	
6	Deposit, from U.F	57,139.30	
14	Dr. Spring travel Joh'bg. Medical Evacuation	491.00	
21	Dr. Purvis Sea Shippment	287.30	
24	R.F.M. Sauti Nigeria Workshop IITA	1,300.00	
28	Dr. McLean Utilities reimbur- sement	188.78	
28	Dr. McLean Half term sch. fees Desig. sch.	415.00	
May			
3	National Seed Co.4000 polli- nating bags Lawson	830.00	
3	Dr. Gray Personal effects Freight	269.42	
12	Parichi Mnyenyembe	130.00	
12	Mrs. E.M. Sibale	200.00	
17	Securicor Services for May	510.65	
18	D.E. McCloud Air ticket Lilongwe to Blantyre	92.00	
18	Computer Equipment Air freight and customs	126.88	
18	National Statistical Office, Publications	71.50	
18	Transfer Hewlett-Packard S. Africa repairs to one HP2631B printer	108.93	
19	Dr. S. F. Pasley, travel reimb.	591.46	
21	D. E. McCloud, reimb. air ticket Nigeria trip	1,214.00	
21	Deposit	2,884.21	
27	Secuircor Services for April	543.55	
28	Dr. A. Hansen, education allow. and trans. reimb.	1,129.76	
June			
6	Securicor Services for June	494.20	
6	Manica, Air Freight on computers	34.87	
7	Deposit, Dr. A. Hansen, reimb.		1,000.00
115	McLean Hotel accommodations	612.96	
15	Manica Freight and Telex Services	5,383.56	
18	D. E. McCloud, reimb. Medical Evac. Mrs. McCloud	491.00	
21	Dr. H.K. Mwandemere, Advance Kenya, Zimbabwe trip	700.00	
21	Dr. S. F. Pasley, Advance Keyna, Zimbabwe trip	1,700.00	
21	Ledger fee	2.50	

Table 3 (Continued)

Date	Details	MK	MK
23	Deposit, Dr. S. F. Pasley, reimb.		500.00
830	Manica Freight and Telexes	1,938.28	
830	National Statistical Office, publications	5.00	
		20,329.44	104,131.54
Less unpresented checks 1		2,556.24	
		17,773.20	
Balance Carried Down			17,773.20
Balance as Per Bank Statement			86,358.34

Table 4

Summary of Expenditures for the University of Florida-IFAS Local Account by Program

April-May-June 1982

Program	Quarterly Expenditures Apr - May - June	Total Expenditures since project began
	K	K
Maize, Breeding and Agronomy	4,447.47	5,395.40
Groundnut, Breeding and Agronomy	7.24	2,764.23
Pasture Agronomy	69.16	9,074.55
Livestock	177.00	4,134.66
Horticulture, Fruits and Vegetables	6,239.01	8,241.29
Agricultural Economics	76.50	1,107.27
Farming Systems	1,680.57	6,063.28
Soil Fertility		1,007.34
Research Coordination	1,928.50	8,290.86
Library		1,599.12
Participant Training		8,199.05
In-service Training	2,835.50	29,858.18
Vehicles First Purchase	----	141,087.64
Overhead1 Not Assignable by Program	3,462.19	61,039.35
TOTAL	20,923.14	287,862.22

1 Overhead should be divided among the following programs: Maize, Groundnut, Pasture, Livestock, Horticulture, Agriculture Economics, Farming Systems and Research Coordination (12.5% each).

Table 5 gives the total expenditures of the project as of 30 June 1982, based on the report submitted to U.S.A.I.D. by the University of Florida.

Table 5. Fiscal Report
April 1, 1982 to June 30, 1982

Contract No. AID/afr-C-1653 (Malawi)
Between the Agency for International Development and the University of Florida

Category	Contract Amount 5/30/80-11/30/84	Budget Amount 5/30/80-5/30/82	To Date 6/30/82	This Period 4/1/82-6/30/82
Salaries and Wages:				
Home Office		$ 112,102.00	$ 79,761.69	$ 11,643.99
Field Office		419,497.00	359,288.46	71,357.46
Indirect Costs:				
Home Office		49,773.00	42,901.66	5,831.07
Field Office		288,926.00	213,861.33	42,241.34
Allowances		92,877.00	31,865.76	6,875.92
Travel and Transportation		172,523.00	246,949.89	51,671.82
Expendable equipment and materials		149,300.00	57,273.79	9,576.75
Non-expendable property		619,000.00*	63,661.27	6,182.12
Participant costs		286,515.00*	307,427.78	53,960.11
Other direct costs		11,440.00	21,447.01	1,565.80
GRAND TOTAL	$ 6,237,029.00	$ 2,201,963.00	$ 1,424,438.64	$ 260,906.38

Computation of indirect Costs:
On Campus: 44.4% x 13,133.05 = 5,831.07
Off Campus: 31.6% x 133,675.13 = 42,241.34

*Indirect costs not taken on equipment items over $500 each or training costs.

IX. PUBLICATIONS

Hansen, A., Mwango, E. N. and Phiri, B.S.C. "Farming Systems Research in Phalombe Project, Malawi: Another Approach to Smallholder Research and Development". 34 pages. To be presented at the Conference on Development in Malawi in the 1980s at Chancellor College, Zomba, 12-14 July 1982. June 1982 Mimeograph.

McCloud, D. E., "Crop Yield Dynamics". 8 pages. Presented at the 3rd African Bureau Agricultural and Rural Development Workshop, Ibadan, Nigeria. May 1982 Mimeograph.

Pervis D.W., "DAR-AREA" Documentation of a computer program to calculate the area of an irregularly shaped field given range and bearing data. June 1982 Mimeograph.

APPENDIX A

FARMING SYSTEMS RESEARCH IN PHALOMBE PROJECT, MALAWI

ANOTHER APPROACH TO SMALLHOLDER RESEARCH AND DEVELOPMENT

By Art Hansen,

Emmanuel N. Mwango,

and Benson S.C. Phiri

Farming Systems Analysis Section

Department of Agricultural Research

Ministry of Agriculture

Government of Malawi

Paper Presented at the 12-14 July 1982

Conference on Development in Malawi in the 1980s

Chancellor College, Zomba, Malawi

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THE FARMING SYSTEMS RESEARCH PROGRAM IN MALAWI

The term "farming systems research" is used in different ways. Some people refer to multiple cropping research, while we and many others mean a more holistic approach that integrates production and socioeconomic scientists (Technical Advisory Committee 1978; Gilbert, et.al., 1980; Collinson 1980; Hansen 1981). The farming systems research program in Malawi is specifically designed to focus on smallholder problems, priorities, and opportunities and to help the Ministry of Agriculture identify high priority problems confronting smallholders in different localities, understand the systemic constraints and opportunities in existing farming practices, and make farm-tested recommendations that are appropriate for smallholder conditions and are acceptable to and desired by smallholders. The basic elements in the farming systems approach are:

-pulling together the various research disciplines and extension in a cooperative series of research and development activities;

-understanding the complexities and interdependencies of localized smallholder economies and ecosystems;

-involving the smallholders themselves in diagnosing local problems and constraints, planning alternative technologies, and then testing and evaluating the alternatives;

-proposing gradual modifications to existing farming systems rather than radical new directions; and

-testing the advantages and costs of proposed innovations under actual smallholder conditions and management.

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The central concept in this approach is the farming system. Hansen, et.al., (1981) define this as "a complicated interwoven mesh of resources and factors (agronomic, economic, social, cultural, physical, etc.) which are managed to a greater or lesser extent by a farmer." This concept includes off-farm resources and factors as well as on-farm ones. The farmer (an individual or family unit) utilizes some of the technology that is available in an attempt to increase the farmer's or farm household's utility within a given context of accepted preferences, aspirations, and socioeconomic conditions. Utility refers to a broad range of satisfactions. For Malawi's smallholders, for example utility obviously includes the production of food, main staples and side dishes, for home consumption, as well as the generation of cash income.

The farming system concept reflects the empirical complexity of the conditions surrounding smallholder agriculture and the complexity of the decisions that smallholders must make. Most of their decisions are compromises in which the farmers balance what they want to gain against their limited time and other resources. Other compromises occur because the farmers' goals conflict: trying to achieve higher incomes versus lower risks, for instance. Consequently, farmers often fail to practice what they know to be "improved" practices (in terms of improving yield) because they are simultaneously trying to maintain a number of enterprises (some of which may be off the farm) to satisfy a range of desires or necessities.

The farming systems approach considers more factors and relationships than single commodity (maize, groundnut, livestock, etc.) or single discipline (agronomy, pathology,

etc.) programs. This does not mean that a farming systems program replaces the more narrowly focused programs. Both are needed to complement each other. The single commodity and discipline programs research in depth specific relationships, while the farming systems program is more concerned with adapting the body of existing research knowledge to smallholder conditions and alerting other research programs to high priority areas where adaptive research is needed.

Although the government of Malawi initiated its farming systems program in 1979 as part of a major upgrading of agricultural research, the first demonstration of the farming systems diagnostic survey (the first step in the four step method) took place in early 1980 when Dr. Mike Collinson of the International Maize and Wheat Improvement Center (CIMMYT) conducted a survey of Ntcheu in Lilongwe Agricultural Development Division (Lilongwe ADD). Dr. Collinson's involvement reflects the interest shown by various international centers and donors in the potential of this approach which is also being established in the neighboring countries of Zambia, Zimbabwe, Kenya, and Tanzania.

The Farming Systems Analysis Section in the Department of Agricultural Research began operations in early 1981 with the arrival of Dr. Ar' Hansen. During 1981 the section conducted diagnostic surveys in three areas of Malawi:

- the Lilongwe Project of Lilongwe ADD,
- the Phalombe Project of Blantyre ADD, and
- the Bulambia plain of Karonga ADD,

and assisted in surveying the Balaka area of Liwonde ADD. Research trials were designed for two of those areas (Lilongwe and

Phalombe) and assistance given to Liwonde ADD in designing its own trials. During this last growing season (1981/82) we have been monitoring these trials, and we are now in process of analyzing the results. This paper discusses our work in Phalombe as an example of how the farming systems approach works to generate smallholder-oriented recommendations. After a brief description of the area and its people, we will trace our involvement, the steps we follow in our approach, and our tentative conclusions at this time.

THE PHALOMBE PROJECT

Phalombe Project is located in southeastern Malawi between Mount Mulanje to the south and Lake Chilwa to the north. The project's eastern boundary is the international border with Mozambique. Much of the area is a colluvial plain at an altitude of 600-700 meters, but the flatness of the plain is broken by a number of steep sided rocky hills and mountains, and the southern half of the project is dominated by the towering bulk of Mount Mulanje which rises to 3000 meters.

More fertile and well drained pediment soils surround the mountains and hills, while the plain is more variable in drainage and soil texture (coarse sands to heavy clays). To the north and northwest the plain slopes down to Lake Chilwa and the Phalombe River which drains into the lake. The heavy clay soils in these lower areas are seasonably or permanently waterlogged (Land Husbandry Unit, Blantyre ADD).

Crops are much more important than livestock to the smallholders in Phalombe. Maize is the most important crop. More than 75% of cultivated land is devoted to maize, usually grown as

the major crop in a field intercropped with pulses, groundnuts, millets/sorghum, and/or cassava (Table 1). Maize, cassava, millets/sorghum, and rice are staple food crops, usually prepared as nsima, while the pulses (primarily cowpeas and pigeonpeas) and groundnuts are grown as relishes (ndiwo), i.e., dishes that accompany nsima. Almost a quarter (23%) of Phalombe rural households own no livestock at all. Although chickens are the most common animal and are owned by almost three fourths (71%) of the households, many (28%) of these households only own one chicken each. Fewer than one sixth (14%) of Phalombe households own cattle, one fifth (20%) goats, and one in ten (11%) pigs.

Unreliable rainfall is a major constraint to agricultural production and stability. Rainfall varies from place to place within the project with higher levels (1000-1300 mm annually) east of Mount Mulanje where agriculture is more secure, lower levels in the central section and along the western flanks of the mountain (averaging 800-900 mm), and dropping off towards the north and west to less than 800 mm a year. The low rainfall in the central, western, and northern sections is compounded by erratic distribution during the rainy season, especially the prevalence of February dry spells when the maize cobs are forming. An analysis of rainy pentades (five day units) for four rain stations in the central and western sections shows that rainfall distribution is adequate for good maize production only one in every four years (Land Husbandry Unit, Blantyre ADD).

Another important constraint for the majority of smallholders is a scarcity of land to cultivate. The population density in Phalombe (121 people per square kilometer) is more than twice the national average, and Malawi is one of Africa's most densely

populated countries (Table 2). Although the average holding size (cultivated land per household) in Phalombe is approximately one hectare (2.5 acres), Table 3 shows that almost a third of the households are cultivating less than half a hectare, and more than 60% cultivate less than a hectare. Land scarcity and the drought-prone climate have induced many men and entire households to emigrate in search of land and employment elsewhere. This emigration explains the low average annual growth rate of the Phalombe population (1.6%) and the high ratio of women to men (Table 2).

The scarcity of adult men is also shown in the high percentage of rural households that are headed by women (37% in Phalombe as compared with 28% for Malawi as a whole). Within Phalombe the sections with the poorest agricultural potential have the highest percentages of women-headed households (Evaluation Unit, Blantyre ADD). Two thirds of these women are unmarried (single, divorced, or widowed). Married women are considered the heads of their households when their husbands return home less than once a month. Labor is an inherent constraint for households headed by women because they usually contain only one adult worker, while most households headed by men also contain another adult worker, the wife.

TABLE 1

CROPS AND INTERCROPPING IN PHALOMBE: 1968/69 AND 1980/81 (a)

	1968/69 Acres	% of Total	% Inter-Cropped	1980/81 Hectares	% of Total	% Inter-Cropped
Maize	25800	81%	96%	29800	76%	92%
Pulses	23600(b)	74%(b)	100%	5100(c)	13%(d)	100%(c)
Millet/Sorgh	18000(b)	56%(b)	92%	5400(c)	14%(d)	63%(c)
Groundnuts	10100(b)	32%(b)	97%	2100(c)	5%(d)	76%(c)
Cassava	6000(b)	19%(b)	77%	3000(c)	8%(d)	30%(c)
Rice	-	-	-	1200(c)	3%(d)	-
TOTAL	31900	100%	86%	39100	100%	75%(c)

a) The National Sample Survey of Agriculture 1968/69 statistics refer to a smaller area than the Evaluation Unit Working Papers, Blantyre ADD 1982, which refer to the present Phalombe Project dimensions. This is why the 1968/69 acreage statistics are so much smaller than the later hectarage statistics. The earlier figures are given as a guide to the extent of multiple cropping and the overlap of land in the various crops.

b) These statistics include many acres which these crops share with maize and sometimes other crops as well, so they sum to more than 31900 acres and 100%.

c) Intercropping and the extent of other crops than maize in 1980/81 are underestimated because intercropped fields are recorded in two categories:

-mixed stand, i.e., more than one major crop in a field, and
-scattered plantings in a field with only one major crop.

Scattered plantings are then joined with monocropped fields to form a "pure stand" category that is opposed to "mixed stand". Only the maize statistics have been disaggregated in this table so that monocropped maize (8% of all land in maize), mixed stands of maize and other crops (43%), and maize fields with scattered plantings of other crops (49%) may be distinguished.

TABLE 2

RURAL POPULATION GROWTH IN PHALOMBE AND MALAWI 1966-1977 (a)

	1977 Population	1966-77 Increase	Mean Annual Growth Rate	1977 Population Density(b)	Women per 100 Men
Phalombe	168,500	19%	1.6%	121	113
Malawi	5,547,500	37%	2.9%	59	107

a) Malawi Population Census 1977: Final Report.

b) This refers to people per square kilometer (121 per sq. km. equals 315 per sq. mile).

TABLE 3

HOLDING SIZE IN PHALOMBE 1968/69 AND 1980/81 (a)

1968/69(a)	1980/81
	31% less than 0.5 hectares
41% less than 0.8 hectares	62% less than 1.0 hectares
81% less than 1.6 hectares	83% less than 1.5 hectares

a) National Sample Survey of Agriculture 1968/69 and Evaluation Unit Working Papers, Blantyre ADD 1982. The earlier survey covered only part of the present project.

b) These were originally expressed as acreage: less than 2 and 4 acres, respectively.

OUR INVOLVEMENT IN PHALOMBE 1981-1982: THE FIRST STEP

Step 1. Review and diagnostic survey May 1981.
Step 2. Plan alternative technologies May-November 1981.
Step 3. Test alternatives November1981-July 1982.
Step 4. Evaluate, recommend, replan Now in process.

The first step in the four step methodology involved reviewing secondary data as well as interviewing local smallholders and observing their fields. Evaluation economists at Blantyre ADD collected and prepared background data to brief the survey team. Project management and extension staff provided information about local cropping patterns they had observed.

The rapid reconnaissance survey (Collinson 1979) or what Hildebrand (1979) calls the sondeo works best when applied to a fairly homogeneous area. Project management noted the high priority of the central section (EPAs 3, 6, and 7), an area of medium rainfall levels where half of Phalombe's population lived, so that was chosen as the focus for the survey.

Ten people, divided into three teams, participated in the survey - three days of interviewing and observing followed by a day of discussion. The group included research agronomists, evaluation economists, crops, land husbandry, and credit staff, an extension supervisor, and the farming systems analyst. Team members were instructed to address smallholders as local experts, people who had survived because they knew their ecosystem. Using a CIMMYT questionnaire (Collinson 1979) as a guide, the survey covered a wide range of topics: cropping combinations and calendars, food preferences, periods of food and labor shortages, local strategies for coping with problems, role of livestock in the system, importance of off-farm

employment and non-agricultural enterprises, common pests and plagues, what smallholders believed to be their major problems, and what they thought the project could do to help them.

The purpose of the rapid diagnostic survey is to form a rapid synthesis of the most important relationships among resources, constraints, and enterprises and the highest priority targets for action by research and development staff. Sometimes a survey team will discover previously unknown facts about the local agricultural and economic relationships. Often, especially in areas such as projects in Malawi where a lot of background data are already available, the survey does not unearth any new data but the survey team becomes more aware and able to appreciate the significance of facts that were already known.

This was what happened in Phalombe. Our conclusions about the basic parameters of smallholder agriculture agreed with the available background information that was presented earlier in this paper, but our recommendations were innovative because we based them on the actual problems and constraints of the majority of Phalombe smallholders. We pointed out that the major hazard confronting local farmers was low and variable rainfall, compounded by a shortage of land to cultivate. Farmers' highest priority was ensuring their staple food supply, and they also needed to acquire relish foods and some cash income. Capital was scarce, and credit was feared because they had no security to cushion a bad cropping season and, therefore, feared the consequences of defaulting. Some households sold maize immediately after harvest because they needed money (taxes, etc.), even though they knew they would run out of food

later. Many farmers and their families worked for others during the growing season instead of on their own holdings because they needed food to eat. Some more fortunate smallholders had more land, more capital, and more security, but we emphasized the conditions faced by the majority.

Smallholders were trying to cope with their problems and constraints by devoting almost all of their land to staple crops interplanted with relish and some market-oriented crops. Insurance staple crops such as sorghum and cassava were grown, often interplanted with maize, to sustain the family if the maize crop failed. Many men and women worked off their farms as laborers or in various kinds of enterprises (fishing and the fish trade, for instance) to supplement their insecure agricultural incomes.

The production packages that were the basis for extension and credit in Phalombe were for acre (or 0.4 hectare) units, were primarily for cash crops, and were integrated packages of seed and several bags of fertilizer that required a lot of capital or credit. All of the research and extension recommendations included monocropping as one aspect. Our recommendations for action by research and the project stressed the need to work with units smaller than an acre and the difficulty for smallholders of taking production packages that required them to assume a lot of credit risk or put in more labor, particularly during the December-January period that was already a labor bottleneck. Since capital and labor were scarce and there was a feeling of insecurity with credit, the best set of innovations would permit a step by step progression with each step not requiring a great jump in resource commitment or risk.

We recommended that research examine improving both the yield and the stability of staple food production within a context of multiple cropping. The primary staple to test would be maize, followed by sorghum and cassava. Legumes (principally cowpeas and pigeon peas) would be an essential intercrop to provide for the relish as well as the staple; additional intercrops could be market-oriented crops such as sunflowers, grams, chickpeas, etc. Trials would be run on local farms under smallholder management to see how they fared under real smallholder conditons.

We recommended that the project promote credit mini-packages of less than acre size; the packages would not be optimal in terms of highest yields per acre but would represent improvements over present practices that were affordable to the majority. For the more fortunate smallholders the present packages were suitable, but the mini-packages would permit many more smallholders to participate in the project's credit program. Another recommendation was that the project examine its extension coverage to see whether women smallholders were receiving enough extension advice. Women provide most of the labor on smallholder crops anywhere in Malawi (Clark 1975), but they are even more important in Phalombe. Chickens were an important source of protein and cash income to many smallholders and were unprotected against Newcastle disease, so we recommended that the project provide vaccine.

THE SECOND STEP: PLANNING

The second step in the farming systems process was to plan alternative technologies based on our survey recommendations and

on joint planning with maize and legume agronomists at Chitedze Research Station and Bunda College and the Blantyre ADD management and technical staff. Because we wanted to run the trials under smallholder management to analyze their systemic adaptation, we did not use standard agronomic research designs such as randomized blocks with multiple replications. Smallholders needed to be able to handle the trials and understand the alternatives, so we used a simpler design in which each smallholder had a single replication of each treatment, and we could use the smallholders as blocks for analysis.

The planning step also included smallholders. After agreement had been reached among research and ADD staff, the farming systems staff called meetings in November in the two Phalombe villages where trials were to be conducted, and we consulted the villagers about their ideas. They contributed specific information about planting densities and dates for intercrops and made several criticisms. As a result, our plans were modified.

The final plans were for a simple 2x2 factorial test of two maize varieties under two levels of fertilizer, all treatments to be the same intercropping mix of maize, cowpeas and sunflowers. The maizes were to be the "local" type and CCA, an improved composite. Although hybrid maizes are the highest yielding, their "dentness" (soft starch) leads smallholders to reject them as a food crop because of their pounding (food processing) and storage characteristics. Hybrids are usually only grown by smallholders as a cash crop for immediate sale after harvest. The improved composites, however, are "flint"

(hard starch) enough to be utilized for home processing and consumption as are the "local" types.

Fertilizer levels were to be: 1) without any fertilizer and 2) at the level recommended for composites - one bag of 20:20:0 and two of S/A per acre (or 2.5 and 5 per hectare). Each of the two fertilizers is 20-21% nitrogen (N), so the recommended level is 30 kilos of nitrogen per acre. Maize and cowpeas were to be planted at the same time, three maize seeds per station three feet (0.9m) apart on ridges three feet apart, while cowpeas were very dispersed, following villager recommendations. Sunflower was to be delayed in planting until after the maize was well established; this reflected smallholder desires to promote the maize crop and treat other crops as bonuses that were not to endanger the staple. Each of the four treatments was to be eight ridges wide and ten maize stations long. This was much larger than usual research plots, but we wanted the smallholders to be able to appreciate any differences in yield, labor costs, etc.

The trials were designed to test how "local" maize and an improved variety fared under identical conditions. We were trying to find out whether fertilizer by itself or improved seed by itself would improve maize yields and stability, which was the highest priority issue noted by the survey. The intercropping pattern was fairly common in Phalombe. Most smallholders mixed maize and cowpea seeds before planting and then planted them in the same stations. Sunflower was the most commonly grown cash crop and was frequently intercropped with maize. The cowpeas would provide relish; the sunflowers a source of cash; and the plot would therefore provide a complete

mix of nsima (staple food), ndiwo (relish food), and ndalama (cash).

In addition to these research trials which were planned as a consequence of the survey, the ADD decided to seriously consider revising its credit and extension policies to include mini-packages and to better address women smallholders. These decisions were based on recommendations by ADD evaluation and project extension staff (Evaluation Unit Working Papers, Blantyre ADD 1981; Evans 1981).

THE THIRD STEP: ON-FARM TRIALS AND MONITORING

The third step was establishing trials. The first phase of this involved the selection of farmers and fields, education of the smallholders in our research design, distribution of seeds and fertilizers, and establishing monitoring procedures. Then the farmers planted, fertilized, and cultivated the plots on their own fields, while we monitored the progress of the trials and continued interviewing the trial farmers and their neighbors to learn their reactions to the alternatives. Whereas most agricultural research focuses on the production, we were interested also in the perceptions and responses of the farmers. Our goal was to provide farm-tested recommendations that smallholders could and would use, so we needed to know socioeconomic as well as agronomic information.

After explaining our purpose and plans to the villagers in public meetings in both villages (project/extension staff always accompanied us in village meetings), we asked each village headman to select eight volunteers to host the trials on their own fields. We requested that the smallholders be those with

less land because they were the ones who needed to intercrop, and we also asked that approximately half be women. As it turned out, the smallholders who were the hosts for the trial were split about half and half between smaller and larger, women and men, and the women between married and unmarried. The total trial thus consisted of 16 farmers in two separate villages.

Each farmer was asked to donate a section of a field, 16 ridges wide by 20 maize stations long. Research and project/extension staff visited each field with the farmer, marked the plots, and took soil samples. In several cases we had to change fields from the ones originally selected by the smallholders because the fields were inappropriate for controlled research.

In two different public meetings we then explained carefully to the smallholders and their neighbors the design of the trial: two plots with each type of maize with a crosscutting application of fertilizers to one plot of each maize. We drew diagrams in the dirt and answered many questions until people were satisfied that they understood what was going to happen and why. As an additional guide the signs given to each farmer to mark each plot were in abbreviated Chichewa (MAK standing for <u>chimanga cha makolo</u> or "local" maize; CCA for CCA and -F for the plots with "feteliza" or fertilizer) instead of the usual scientific shorthand.

When we distributed the seed and fertilizer, along with a regulation cup for applying the fertilizer, we again explained the research design. In addition to giving the farmers the inputs, we also discussed the prices each cost at the government outlet (ADMARC), the units in which they were sold, and the

correct timing for applying fertilizers to maize. When someone commented on the unusual color of the CCA seeds, we explained the reason why they had been coated with a chemical. This turned out to be important because later on, when planting was delayed in one village, one elderly woman ate the "local" maize because she was hungry. She then told us she would have eaten the CCA also if she had not learned from us about the poisonous coating.

The farmers provided the actual labor and management for the trial. Each week each of them was visited by a local research or extension agent, and each month we visited from Lilongwe. The weekly visits noted the dates of significant operations (plantings, weedings, fertilizer applications) and natural occurrences (rain, army worms, etc.) and the condition of the treatments. The agents also offered advice concerning the trial plots.

Farming is a risky business. The farmers and we suffered through an early drought that caused all of the farmers in one of the villages to have to replant their maize in late December (a month later than the usual planting time), a damaging blow in an area where the rains often stop too early. When the rains came, so did erosion in one village where people were cultivating hillside slopes. Then army worms attacked in many areas of Phalombe (and other areas in Malawi), and there were always stalkborers and termites to combat. We had originally intended not to use any pesticides and to expose our plots to the same uncontrolled environment of pests that regular fields confronted, but we changed our minds when the plots were really attacked and distributed insecticides for the farmers to apply.

This is one reason why our final yields are much higher than the local averages.

Our Monthly visits combined inspecting the trial plots and interviewing the trial farmers about their reactions with continuing investigations into Phalombe smallholder farming. During each visit the farming systems staff met with the project management to talk about the progress of the trials; this continual interaction between research and extension is necessary to ensure that extension staff understand the trials and can successfully extend their lessons to local smallholders.

[illegible] we conducted a special multiple cropping survey for three days to suoplement the data collected in the original farming systems survey and by evaluation. Although the 1981/82 trial had a standard intercropping pattern in all four treatments, intercropping is a variable that needs to be investigated under Phalombe conditions, and the next research trial will probably consider various intercropping mixtures.

In May we harvested the maize (the sunflower only being harvested in June - [illegible]). In each village the trial farmers helped us harvest each others' plots so all would have the opportunity to see how the treatments responded in various ecological niches. Since smallholders are more accustomed to evaluating or measuring volumes than weights, we measured the yield from each treatment both ways, using a scale for weight and a standard [illegible] ated tin for volume. After harvesting all of [illegible] we called another meeting in each village to discuss our perceptions of the different treatments.

At both meetings we began by reminding everyone of the original purpose of our presence and the trials, and then we

began to compare our evaluations. Here was the beginning of the fourth step in our four step process - evaluating the trial and deciding whether we could make any recommendations and/or whether we needed to plan again another set of trials.

THE FOURTH STEP: EVALUATION, RECOMMENDATIONS, OR PLANNING AGAIN

The yields that were harvested from the plots of the eight farmers in one village and the six in the other (two farmers were omitted due to problems with erosion and poor germination) are presented in Table 4. The statistics represent metric tons per hectare (M.T./ha.) of usable grain. Usable grain was defined by the smallholders themselves as they worked with us to shell and weigh the harvest. They eliminated all rotten grain and that which was very badly eaten away by weevils. As has been noted by the Crop Storage Research Section (Annual Report 1979/80), smallholder criteria for defining usable and unusable grain differ from the criteria used by laboratory technicians, who discard all grain that has been attacked at all by insects.

We asked the trial farmers to share with us their ideas about which variety grew best and about the value of fertilizer. After they gave us their impressions, we reciprocated by telling them our preliminary assessment, based on a comparison of the means for the treatments and the differences among smallholders. For clarity, we will start here with a review of the actual yields we recorded and our interpretation of those yields before discussing what the smallholders said in the meetings.

TABLE 4

MAIZE YIELDS FROM PHALOMBE ON-FARM FARMER-MANAGED TRIAL 1981/82

Usable Grain in Metric Tons per Hectare (M.T./ha.)

FIRST VILLAGE

4 TREATMENTS	8 FARMERS								
	1	2	3	4	5	6	7	8	Mean
Local Maize (LM)	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	3.2
CCA Maize (CCA)	3.5	2.0	2.9	0.4	0.6	0.5	0.6	0.3	1.3
Fert. CCA (CCA-F)	5.0	4.7	4.3	3.5	2.4	1.7	3.0	2.8	3.4
Mean for Farmer	3.6	3.2	3.3	2.1	1.7	1.3	1.9	1.6	2.3

SECOND VILLAGE

4 TREATMENTS	6 FARMERS						
	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	2.5	2.1	1.1	0.8	0.4	1.6
Mean for Farmer	2.5	1.7	1.9	0.9	1.4	0.5	1.5

Table 4 shows obvious differences: 1) between the means for villages, 2) among the means for farmers in each village, and 3) between the means for the two fertilizer levels in the first village. The difference between the two villages is easily explainable by reference to rainfall and the time the maize was planted. Both villages planted in late November, but the second village did not receive enough rain to sustain the maize and had to replant in late December after they received their first real planting rains. The first village received enough rain in late November and early December, so their maize had a month headstart. The second village also suffered severe attacks by army worms in January, but this was less of a factor than the rain and time of planting. Yields in the first village, therefore, show how the treatments responded to better conditions. Smallholders anticipate planting in late November, so perhaps the first village conditions might be considered more normal. Yields in the second village reflect the adverse conditions that continually threaten Phalombe agriculture.

We were testing two varieties under two levels of fertilizer. What is very clear in Table 4 is that both maizes responded strongly to fertilizer. Both "local" and CCA more than doubled their yields in the first village under better conditions, although the effect of fertilizer was not as marked in the second village with its generally lower performance. What is also apparent is that there was little difference between the two maizes at either level of fertilizer in the first village under better conditions, and "local" performed somewhat better in the second village under poorer conditions.

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These conclusions were supported when we later ran analyses of variance on the yield data. The analyses apportioned the total variance among the treatments, the blocks (farmers), and the individual values (random/error): the higher the mean square the greater the variance attributed to that factor. In the analysis of the combined villages we used the villages as blocks and the farmers as replications within each block. The F ratio expresses the difference between the mean squares of that factor and of error: the higher the ratio the more unlike are the two populations. The significance statistic expresses the probability that such a difference was not caused by chance.

Table 5 shows that the fertilizer effect was highly significant (>99%) in the first and in the combined villages, and it was significant in the second village. The variable of maize type was never significant. The differences among farmers were significant in each village, and the difference between the two villages (explained above by reference to rainfall and time of planting) was highly significant. Differences among farmers will be addressed after first discussing the maize type versus fertilizer issue.

The importance of fertilizer to maize yields is obviously supported by our data, but the insignificant relationship between maize type and yield needs to be examined more closely. This set of relationships may also be studied in the yield data collected by the Evaluation Unit of Blantyre ADD during the 1980/81 National Sample Survey of Agriculture. They sampled many smallholder maize plots in Phalombe during that cropping

TABLE 5

ANALYSES OF VARIANCE RESULTS (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	Insignificant
Fert x Maize	1	Insignificant		
Error	21	1.635		
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	Insignificant
Fert x Maize	1	0.010	Insignificant	
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	Insignificant	
Vill x Fert	1	3.676	3.45	93%
Vill x Maize	1	1.403	1.32	Insignificant
Fert x Maize	1	Insignificant		
Error	49	1.066		

a) In the analyses for the 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 replications (farmers) in the first village/block and six in the second

season, although there were very few fields (only 12 in their sample) with anything other than "local" maize. All of those 12 were UCA, another composite similar to CCA. Their data show a significant difference in mean yield between "local" and UCA, but that difference appears to be largely a matter of differential fertilizer application rates (Table 6).

TABLE 6

SMALLHOLDER MAIZE YIELDS X FERTILIZER: PHALOMBE 1980/81 (a)

FERTILIZER APPLICATION (kilos/ha.)	"LOCAL" MAIZE YIELD (M.T./ha.)	NUMBER OF PLOTS	UCA MAIZE YIELDS (M.T./ha.)
None	0.8	431	1.8 for 12 plots
1-49	1.6	5	throughout the
50-99	1.3	21	Phalombe Project
100-149	1.3	22	
150-199	1.4	19	1.5 when plots
200-249	1.9	6	in EPA 8 (area
250-299	2.0	4	with highest
300-349	1.9	6	rainfall) are
350+	1.2	6	excluded

a) Data provided by Evaluation Unit, Blantyre ADD.

When comparisons are made between the two maize types at similar levels of fertilizer, the differences in yield are greatly diminished. Recommended levels of fertilizer for composites (UCA and CCA) are three bags (150 kilos) per acre or 7.5 bags (375 kilos) per hectare. "Local" maize yields equal the mean for UCA once 200 kilos are applied (four bags per

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hectare or 1.6 per acre).

Another important aspect that we were studying was yield stability. Farmers want higher yields of the staple, but they also want a more secure or stable production. Stability of the two maize types may be measured to some extent from our data (Table 4) by looking at the range of yields, i.e., more stability may be defined as reduced variability. The coefficients of variation (c.v.) in Table 7 measure the extent to which the individual yield values deviate from the mean. This statistic is corrected for the magnitude of the different means (c.v.= standard deviation divided by mean), so all of the c.v. values in Table 7 are directly comparable: the higher the c.v. the more variable and unstable. As may be seen, "local" maize is more stable than CCA in each village and under both fertilizer conditions. The inverse of stability may be responsiveness; CCA is more responsive to its environment, whether adverse or favorable. Both maizes are more stable when fertilized (except for "local" in the second village), a feature most noticeable in the first village under better growing conditions.

TABLE 7

YIELD STABILITY AS MEASURED BY COEFFICIENTS OF VARIATION

FIRST VILLAGE		SECOND VILLAGE		BOTH VILLAGES	
Treatment	**c.v.**	**Treatment**	**c.v.**	**Treatment**	**c.v.**
Local Maize	45	Local Maize	35	Local Maize	39
Fert. Local	22	Fert. Local	45	Fert. Local	35
CCA Maize	98	CCA Maize	78	CCA Maize	88
Fert. CCA	34	Fert. CCA	63	Fert. CCA	52

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The smallholders are concerned about both yield and stability, and both improved with fertilizer. Unfortunately, fertilizer is a costly input, and the lack of capital and fear of credit inhibit people from acquiring fertilizer. For this reason we carefully examined the costs and benefits of applying fertilizer in our trial.

Fertilizer costs per hectare total K61.25 (61.25 Malawian Kwacha) at the recommended rate of one bag (50 kg) of 20:20:0 and two bags (100 kg) of S/A per 0.4 hectare (one acre), using the 1981/82 ADMARC selling prices of K8.50 per bag of 20:20:0 and K8.00 per bag of S/A. Seed costs per hectare for CCA are K6.25 at the recommended rate of one 10 kg bag per 0.4 hectares and the 1981/82 selling price of K2.50 per bag. ADMARC is buying maize in 1982 at K0.11 (11 tambala) per kg or K11 per 0.1 metric tons (M.T.). Thus, a yield increase of 0.6 M.T. is more than enough to offset the cost of fertilizer (0.1 M.T. will pay for CCA seed costs for a hectare).

Table 8 shows that fertilizer is profitable to apply to both types of maize in both villages, although there is very little average profit in the second village. Examining individual cases, each of the eight farmers in the first village and 50% of those in the second would have made a profit by fertilizing and selling the extra yield. Unfortunately, 50% in the second village would have lost money.

This brings us back again to the variability among smallholders, which was significant in both villages. Graph 1 illustrates this by plotting the mean yields (combining both varieties) of all fourteen farmers.

TABLE 8

PROFITABILITY OF FERTILIZER APPLICATION TO MAIZE (M.T./ha.)

Each Metric Ton is Worth 110 Malawi Kwacha at 1982 Prices

	FIRST VILLAGE		SECOND VILLAGE	
MAIZE TYPE	YIELD INCREASE WITH FERTILIZER	PROFIT	YIELD INCREASE WITH FERTILIZER	PROFIT
Local	1.8	+ 1.2	0.8	+0.2
CCA	2.1	+1.5	0.7	+0.1

GRAPH 1

SMALLHOLDER YIELDS BY VILLAGE AND FERTILIZER RATE

The Graphed Values Represent the Means for Combined Maize Types

First Village 1-8 Second Village A-F

		NO FERTILIZER			
FERTILIZER					
	4.5			1,3	
	4.0			2	
	3.5			4	
Yield	3.0	1		7,8,9	A
in	2.5	3		5	B,C
M.T./ha.	2.0	2	A	6	
	1.5		C,E		E
	1.0	4,5,7	B		D
	0.5	6,8	D,F		F

Three smallholders in the first village (numbers 1-3) achieved yields of 3.5 M.T./ha. or better on all of their fertilized plots (and >4.5 on two plots) and generally demonstrated the advantage of CCA over "local" in high-yielding

situations. The other five farmers in the same village (4-8) harvested 0.6 M.T./ha. or less on their plots of unfertilized CCA, severely depressing the mean for that treatment, and their plots showed no differences between maizes or, with the lowest yields, the advantage of "local" stability.

Why the gap between 1-3 and 4-8? We are unable to answer that question satisfactorily because our research design focused on the treatments rather than the farmers (blocks). Probably part of the answer lies in differential residual fertility of the trial fields. Fertilized tobacco had been planted the previous year in the fields of two farmers (1,2), but this relationship has not yet been tested.

Another part of the answer is associated with the relationship among tobacco growers, larger holdings, and higher yields. Four farmers (1-3,8) in the first village are tobacco growers (none of them women), and tobacco is only grown in this area by those with enough landto alienate some from food crop production. Of the other four farmers in the village, one was sick a lot; another experienced serious domestic problems (influencing labor availability); and a third did not weed on schedule.

The range of variability in the second village was not as great, perhaps because the delayed planting depressed the multiplier effects of residual fertility and differential management. Farmer A may have achieved his higher yields because of his slightly different ecological niche (more rainfall), but the more interesting question raised in this village by Graph 1 is why two farmers (E,F) showed no response to fertilizer, and another only a minimal response.

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Smallholders A-C showed impressive yield increases with the application of fertilizer (as did 1-8 in the first village), but D-F did not, an anomaly for which we do not as yet have an answer.

The preceding is our evaluation of the maize yield results. Another important contribution was made by the smallholders themselves in our summary meetings after the harvest. In some ways their comments supported our own thoughts, but in other ways they differed.

Smallholders in the first village agreed that fertilizer was an important input, but they all complained about the cost and the difficulty of getting credit for fertilizer. One of the farmers with less land complained that she wanted to grow a cash crop or a crop on credit, but all of the packages were for an acre. An acre was all the land she had, and putting it into the credit crop meant taking it away from staple food production, which she could not afford to do. When we mentioned the possibility of sharing a credit package with a friend (one way to lower the cost), the universal reply was that "You cannot trust a friend." They all wanted to be individually responsible for what they received on credit and not be jointly responsible with someone else.

The farmers in the first village surprised us, however, with their comments about CCA maize and ADMARC. When we asked them to compare the two maizes, we expected them to say they saw little difference. The most successful farmers (1-3) replied first, and they said that CCA was better than "local" at both levels of fertilizer. In fact, as was mentioned earlier, CCA

did better for those farmers with the highest yields. The less successful farmers (4-8), who had actually experienced no difference between maize types or had better success with "local", verbally supported the first to speak and noted how much better CCA was. Their only dissent was to mention the increased susceptibility to weevil damage of the composites (UCA more than CCA).

The mention of weevil attacks started a series of comments. Villagers criticized the composites for their vulnerability to weevil attacks and complained about the delay in opening ADMARC markets where the smallholders could sell their maize. Maize is harvested in April, but the ADMARC markets did not open for several more months. By the time the markets had opened, stored composites were already badly weeviled, and this inhibited people growing composites for sale. The delayed opening of government buying points obviously does act to the disadvantage of local farmers. We noticed many farmers selling maize to private traders at prices well below the ADMARC price. When questioned about the sales, the farmers pointed out that they needed money then and could not wait for several months. Other comments about ADMARC reflected what appears to the senior author of this paper to represent a universal suspicion by farmers of whoever markets their produce. Farmers voiced suspicions about being cheated and shortchanged because they could not see the scale where their produce was being weighed. Placing the scale in a place where it could be seen seems a small step, but it would reduce farmer discontent.

SUGGESTIONS FROM THIS RESEARCH

Based on the results of this first year's research, we may make some qualified suggestions. They must be qualified because they only represent one cropping season and part of Phalombe (two villages in two of the six EPAs). The villages differed in rainfall, but they are located in the central section of Phalombe, not in the wettest nor the driest areas, and each cropping season confronts smallholders with new risks.

1. We suggest that the project make credit available for fertilizer to be used on "local" maize.

2. We suggest that the project permit smallholders to get credit in units smaller than 0.4 hectares (one acre).

3. We suggest that research and extension (the project) examine the utility of multiple cropping for smallholders with limited land resources before making blanket recommendations for monocropping.

4. We suggest that ADMARC consider opening its buying markets in Phalombe earlier (perhaps late April) and moving its scales so that farmers can see what their produce weighs.

5. We suggest that on-farm farmer-managed comparisons of composites and "local" maizes be conducted elsewhere to check their performance under other management conditions. The farmers who manage the trials should represent a spectrum of resources and experience.

6. We suggest that research investigate the effects of pest damage on maize yields and the effectiveness of variable cost control measures by conducting on-farm farmer-managed trials.

Other suggestions were made earlier as a result of the initial diagnostic survey.

PLANNING THE NEXT GENERATION OF TRIALS

The 1981/82 trial examined the relationship of maize type, fertilizer, and yield. Multiple cropping was held constant, and farmer management was not critically examined. Next year's trials need to examine:

1. maize responses to varying levels of fertilizer (many farmers only apply one bag per acre/field) since farmers need information about the costs and benefits of minimal increments;

2. maize yields under conditions of monocropping and intercropping;

3. various multiple cropping mixtures in terms of the maize yield and provision of cash income (maize yield being higher priority); and

4. farmer management practices and their effects on yield.

The first three may be easily handled using the same format as we used in 1981/82, i.e., on-farm farmer-managed trials with a few treatments. The fourth factor will be more difficult to test, and we have not yet determined the best format.

SUMMARY

The farming systems approach to smallholder research differs from other research programs in many ways. This paper describes our involvement in one locality, and those who are familiar with agricultural research will be able to note the differences in technique. We stress a prior understanding of local smallholder systems, an integrated team of production and socioeconomic scientists and development staff, continual involvement of smallholders in all stages of research, on-farm

trials that are managed by smallholders, and selecting smallholders who represent the majority to test our proposed alternatives.

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CROP YIELD DYNAMICS

D. E. McCloud, Professor and Chief of Party
University of Florida/USAID Malawi Contract

For discussion at the third African Bureau Agricultural and Rural Development Workshop held at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, May 10-13, 1982.

Today I would like to discuss with you some aspects of how yield is determined in most crop plants. First we will consider the basic agricultural yield of one ton per hectare which, until recently, has been the maximum obtainable agricultural yield for most of the 10,000 years since the begining of agriculture. Secondly, we will discuss the ecological factors affecting agricultural yield. Thirdly, I will present a simplified method for calculating potential yield in crop plants. Lastly, we will discuss crop yield variability.

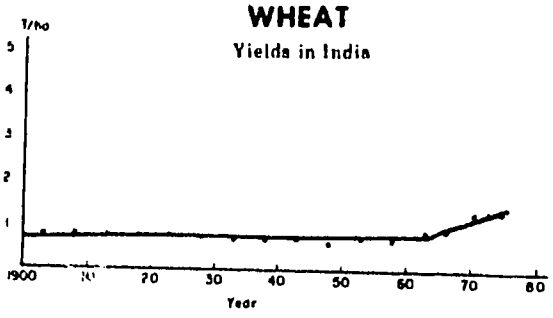
BASIC AGRICULTURAL YIELD

Agriculture is quite recent in terms of man's existence. It dates back only 10 to 12 thousand years to the Neolithic Age. The development of agriculture followed two major patterns: 1) those systems based on restricted areas of highly fertile soils, usually the river alluvium (fluvisols) or productive terrace soils (andosols), both of which took advantage of a fertile soil which is periodically enriched by the drift of water borne or wind borne materials, and 2) the system of Shifting Cultivation which takes advantage of the large supply of nutrients available from the native forests or grass vegetation. Nye has estimated that over 200 million people thinly scattered over 36 million square kilometers of the tropics obtain the bulk of their food by Shifting Cultivation. They account for less than 10% of the world's population, but are spread over more than 30% of its exploitable soils.

Although Shifting Cultivation is often regarded as a primitive system of agriculture in the tropics, its practice was not confined to the tropics nor are the peoples who employ it necessarily primitive in technology or in culture. The English settlers in Virgiania in the 17th century adopted Shifting Cultivation from the Indians, who had found it to be the best answer to conditions in which there was abundant forest, difficult to clear for plowing, and no other system for maintaining fertility. Shifting Cultivation persisted in areas of Europe during the Middle Ages. Sedentary Subsistence Farming, the manoral two course rotation system, which is a form of intensive Shifting Cultivation followed as the next agricultural system.

In both Shifting Cultivation and Sedentary Subsistence Farming, crop yields did not exceed 1.0 ton per hectare. One ton per hectare is equal to 100 grams per square meter; this is the basic agricultural yield.

Wheat yields in India are an example. For centuries, ever since wheat was first grown in India, and until the Green Revolution beginning in the mid-1960's, wheat yields remained almost constant at just under one ton per hectare, Fig. 1.



From: MAN'S FOOD CROP RESOURCES
Professor D. E. McCloud
Institute of Food & Agricultural Sciences
University of Florida 1979

Fig. 1 Wheat Yields in India since 1900

During the 18th century a new farming system developed in Europe. Livestock Farming enabled farmers to double grain yields to 2 tons per hectare. The New Agriculture was a system in which cereals and other food crops were rotated with clovers and grasses for nitrogen fixation and feeding of livestock. All the urine and manure were carefully saved for the cropland, and much attention was given to the collection of refuse and night-soil from the towns to be put on the grain crops. Livestock Farming was hailed as a revolution in agriculture.

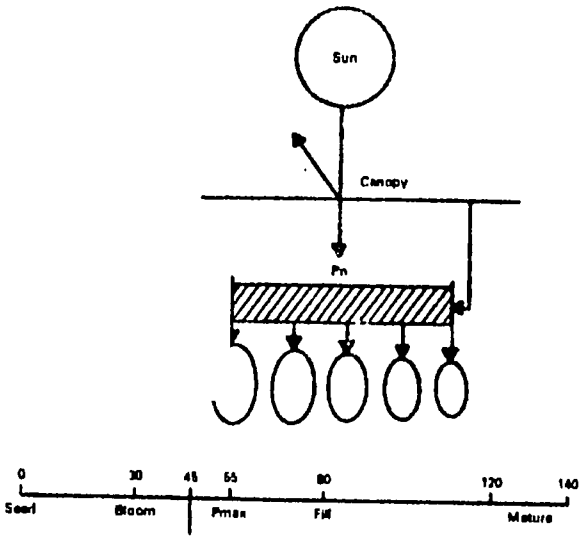
The next break-through for increasing agricultural yields came as a result of the discovery of a method of manufactuing fertilizer. This led to another doubling of crop yields to 4 tons per hectare. This stage of agricultural development is called Industrialized Agriculture. With the development of new fertilizer-responsive varieties, the application of high levels of fertilizer made possible still another doubling of yields -- to 8 tons per hectare. This yield is near the maximum average yield for grain crops.

ECOLOGICAL FACTORS AFFECTING YIELD

The primary ecological factors affecting crop yields are solar radiation, temperature, precipitation and plant nutrients. Plant pests, including weeds, diseases, insects and nematodes, can also reduce crop yields. For the purposes of calculating potential yield we will assume that all pests are controlled.

Solar Radiation

Solar radiation by means of the photosynthetic process in plants "drives" dry matter production or growth. Solar radiation sets the ceiling on daily dry matter production, it fills the "tank" in the diagram, Fig. 2.



From: Physiological Basis for Increased Yield Potential in Peanuts
D. E. McCloud et al
ICRISAT Proceedings of the International Workshop on Groundnuts 1980

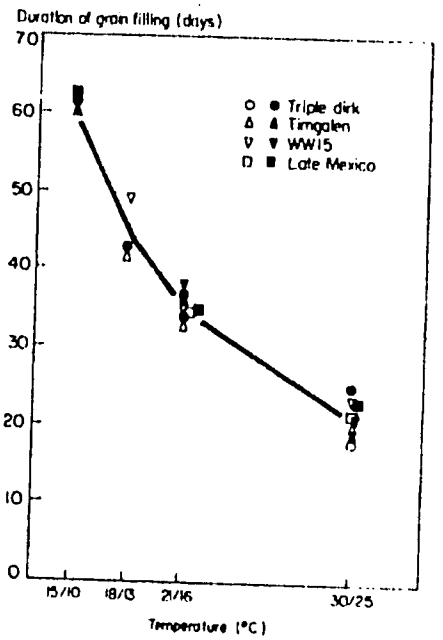
Fig. 2 Diagrammatic Representation of a Crop Production Model

Crop plants, if high yields are to be obtained, generally attain complete ground cover at the on-set of grain filling. Light interception is virtually complete at a LAI of about 3. Plant density inversely affects the time required to reach full ground cover. The higher the density the shorter the time to complete ground cover. Following complete ground cover a higher LAI may be produced if vegetative growth continues, but the crop growth rate is at its maximum, and the additional leafage does not produce additional photosynthate since light interception has already reached 100%. When grain numbers are being set, the crop growth rate should be at its maximum if potential yields are to be achieved. Vegetative growth should also cease so that all photosynthate can go to grain formation. This period is very critical in determining yield. In contrast, variations in solar radiation during the vegetative growth period has little or no effect on yield.

Temperature

Temperature "governs" the rate of plant development, and it sets the length of the growing season. The length of a particular phenophase (growth stage) is inversely related to temperature, the higher the temperature the shorter the phenophase. In grain crops, the rate of filling of an individual kernel is set by the enzymatic rates within the kernel which are temperature regulated. Thus, it is temperature that determines the rate of filling of individual grains. Actual grain numbers are determined by the daily photosynthates available for grain filling divided by the fill rate of an individual kernel. The supply of daily assimilates is determined by solar radiation. For example, a lower temperature produces slower individual grain filling rate with less photosynthate going to each kernel. More grains can be set with the same amount of daily photosynthate. Potential yield will be higher and the filling period longer.

The effect of temperature on the duration of the grain filling period in four cultivars of wheat is shown in Fig. 3. The open vs. closed symbols indicate two different solar radiation levels which are not different.



From: Phytotrons in Agricultural Research
L. T. Evans
IRRI Proceedings of the Symposium
on Climate & Rice 1976

Fig. 3 Effect of Temperature on Duration of Grain Filling

Thus, temperature indirectly plays a major role in determining yield. That is why most crop plants produce their highest yields near the limits of their adaptation at poleward locations or at higher elevations in the tropics.

Temperature, in combination with water availibility, also sets the length of the growing season. In temperate climates low temperatures in the spring and fall determine growing season length for the various crops.

Precipitation

Where temperatures permit crop growth, rainfall is the major climatic element that affects crop growth and development. In most agricultural areas rainfall data is available from an extensive network of stations. For specific sites soil-water balance models can be developed. In general, however, 5 mm per day is considered adequate for crop growth, and most soils store about 100 mm of available water which would be exhausted after 20 days. Where irrigation is practiced, a 50% depletion factor generally is used for replenishment. Under drought stress photosynthesis is the first physiological factor to be affected, and this stops dry matter accumulation.

In crop growing areas, rainfall, along with temperature, determines

the length of the growing season and often sets the ceiling on crop production. Thus, precipitation plays a major role in both determining crop adaptation and yield.

Plant Nutrients

The primary effect of mineral nutrients on yield of crop plants is by their effect on photosynthesis. Nutrient effects on photosynthesis can occur directly or indirectly. An important indirect effect is the nitrogen-responsive, short-stature, non-lodging cereal crops. Nitrogen deficiency occurs the most frequently and has the most pronounced effect on photosynthesis. Potassium deficiency is usually less pronounced than the effect of nitrogen, but it can have very striking effects on stomatal closure which results in reduced photosynthesis. Longer periods of phosphorus deficiency do reduce photosynthesis, although short periods of moderate deficiency have no effect. Thus, a deficiency of any of the macro-nutrients can have a deleterious effect on photosynthesis.

Magnesium is required in the enzymes involving energy transfer and as a part of the chlorophyll molecule. Severe deficiencies of magnesium do sharply reduce photosynthesis. Sulfur is essential for protein synthesis, and the importance of proteins to photosynthesis is consistent with the major effects of a sulfur deficiency on photosynthesis. Calcium deficiencies, on the other hand, regardless of how severe have no effect on photosynthesis.

The role of the micro-nutrients except for manganese is less well understood. A manganese deficiency has been shown to reduce photosynthesis. While iron, zinc, and copper do cause chlorosis in plants, their role in reducing photosynthesis has not been established.

POTENTIAL YIELD

In grain crops the potential yield, when water, plant pests, and nutrients are not limiting, is determined by the interaction of temperature and solar radiation during the grain filling period.

Solar radiation drives the photosynthetic process which produces the dry matter for grain filling, but little or no photosynthate produced prior to the onset of grain filling contributes to final yield. Thus, only the solar radiation received during filling contributes to yield. When solar radiation is expressed in MJ per square meter, the dry matter produced is in grams per square meter since the relationship is 1:1. Thus, 20 MJ per square meter per day will produce 20 g per square meter dry matter. If solar radiation is expressed in langlys these units should be multiplied by 0.04 to convert to MJ/m2.

Temperature, on the other hand, governs the rate of plant development. During grain filling the slower development at lower temperatures, with slower filling rates for each kernel, means a larger grain number and a longer filling period -- resulting in higher yields.

Temperature determines the length of the grain filling period, and solar radiation during filling, delimits the daily dry matter produced. Together, these two factors determine the yield produced by the crop. The equation is:

Potential Yield = Solar Radiation MJ/m2/da x Days Filling x Grain Composition Factor x Partitioning Factor

Days filling can be determined by the time between heading and physiological maturity. The grain composition factor is 1.0 for the cereal grains. For peanuts it is 0.6 since more photosynthate is required to produce oil and protein compared to carbohydrate. With soybeans the grain composition factor is 0.7. The partitioning factor for peanuts can vary from 0.4 to 0.8; for most soybean cultivars it is 1.0; and for maize and the cereal grains it is also 1.0.

Some examples of the Potential Yield calculation are given in Table 1.

Table 1 Solar Radiation, Days Filling, and Actual vs. Calculated Yields of Rice at Several Locations.

Location	Solar Radiation MJ/m2/da	Filling days	Actual g/m2	Potential g/m2
Los Banos wet	14.7	30	450	441
Los Banos dry	21.1	30	650	633
Pelotas	16.6	29	300	481
Chikugo-Shi	12.8	54	640	691
Stoneville	19.0	34	504	646
Yanco	22.5	59	740	1,327
Hokkaido	13.9	53	601	737

Source: G. W. Robertson 1975 Rice and Weather Technical Note 144 World Meterological Organization Geneva, Switzerland 44 pp

At Los Banos, Philippines in both the wet, low radiation and the dry, high radiation seasons actual vs. potential yields differed by less than 3%. At Chikugo, Japan actual yield was 8% less than potential. For Pelotas, Brazil; Stoneville, U. S. A.; and Yanco, Australia; dryland rice suffered moisture deficiencies at the critical heading stage reducing actual yields. At Hokkaido, Japan, cool temperatures at heading reduced grain numbers lowering actual yields.

This method is simple and is physiologically sound, and the calculation of potential yields can be used to obtain estimates of actual yields. It is useful particularly in less developed countries to provide an indication of expected yields under optimum

conditions. In maximum yield trials the method can be used to determine potential yields for various crops.

CROP YIELD VARIABILITY

In analyzing a long-term series of crop yields for any given location, the first step should be to establish whether a Technology Trend exists. This trend may be linear or exponential, and it is best measured by the Technology Trend Index, which is:

Technology Trend Index = Regression Slope / Mean Yield x 100

Crop yields in a given area are dependent primarily upon the level of technology, climatic and soil conditions. An analysis of a long-term series of crop yields will reveal whether the crop is grown under ecologically optimum conditions. The year to year fluctuations in yield around the trend line are due mainly to climatic differences. There may of course be variable inputs, diseases, insects, or other pest induced yield effects, but generally these are small compared to the climatic fluctuations.

The second step is to determine the Environmental Index, which is measured by:

Environmental Index = Standard Error of the Estimate / Mean Yield x 100

The Standard Error of the Estimate is a measure of the fluctuations around the trend line. Table 2 gives calculations of these indices for six locations from data given in Table 3. The six locations were chosen from regions in which a large porportion of the arable land grows the crop. The Illinois corn data was taken from Piatt county, one of the best corn growing regions in the United States. The Japanese rice data was taken from Hokkaido, one of the most northern rice growing regions in the world. Zimbabwean wheat is from the irrigated wheat growing regions in that country. Canadian wheat is from a northern, extensive wheat producing country, while Indian wheat represents one of the most tropical countries where wheat is grown. Malawi represents an intensive maize growing country; the same proportion of the arable land is planted to maize in Malawi as is planted to maize in Illinois.

Table 2 Mean Yields, Techology Index and Environmental Index for Six Cropping Regions.

	Illinois Corn	Japan Rice	Zimbabwe Wheat	Canada Wheat	India Wheat	Malawi Maize
Mean Yields t/ha	5.29	3.92	2.89	1.58	1.03	1.12
Technology Index	2.6	1.1	1.6	2.5	3.8	0.2
Environmental Index	12.2	18.0	42.1	12.7	9.3	10.7

Mean yields of maize are high in the U. S. corn belt with excellent soils, favorable climate and high levels of fertilizer. Some improvement in technology can be detected since 1957 (2.6%). That the environment is favorable is shown by a variability of 12.2% and this includes the corn blight year of 1970. In comparison rice yields at Hokkaido, while high, show only a 1.1% technology trend, and an 18% environmental variability -- a result of too cool temperatures some years. Zimbabwean wheat, while high yielding, has a 42.1% environmental variability, likely due to the higher temperatures in some years. Canadian wheat is lower yielding, often because of droughts on the western prairies. Indian wheat showed the highest technology index (3.8) a result of the Green Revolution. Malawian maize had the lowest technology trend (0.2%), but climatically maize is as well adapted to Malawi as it is to the central U. S. corn belt, as shown by the low (10.7%) environmental index for Malawi. The data used to calculate these indices are given in Table 3.

Table 3 Crop Yields from 1957 to 1980 for Six Locations.

Year	Illinois Corn	Japan Rice	Zimbabwe Wheat	Canada Wheat	India Wheat	Malawi Maize
	bu/A	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
1957	74	3320	1480	1230	700	--
1958	79	3830	1090	1200	680	--
1959	75	3920	940	1200	790	--
1960	90	4000	1270	1420	770	--
1961	90	4260	1960	750	851	--
1962	104	3560	1480	1330	890	--
1963	107	3960	1760	1770	793	--
1964	97	2640	2180	1360	730	--
1965	115	3340	2670	1540	913	--
1966	87	2830	2270	1870	824	1200
1967	120	4520	2780	1320	887	1270
1968	95	4740	3390	1490	1103	1089
1969	116	3510	3450	1840	1169	998
1970	100	4430	3670	1790	1209	900
1971	123	2730	4020	1830	1307	1100
1972	129	5000	3730	1680	1380	1216
1973	125	4790	3940	1670	1271	1145
1974	92	5030	3590	1790	1158	1019
1975	145	4460	4090	1740	1338	1000
1976	143	3610	4300	2056	1410	1100
1977	128	--	4030	1942	1394	1200
1978	--	--	4530	1999	--	1273
1979	--	--	4640	--	--	--
1980	--	--	4850	--	--	--

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AGRICULTURAL ECONOMICS SECTION
CHITEDZE AGRICULTURAL RESEARCH STATION

D.W. Pervis

DAR-AREA
June, 1982

Computer Program Document

Purpose: To calculate the area of irregularly shaped farmers fields, given range and bearing data.

How to Use: The program is written in HP-85 Basic Language and is stored on tape at the computer facility of the Agricultural Economics / Farming Systems Sections. To access the program, you must request the correct tape from Agricultural Economics and load the file as follows:

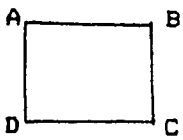
1. Insert the tape
2. Press LOAD
3. Type "AREA" and press END LINE
4. Press RUN

The program will ask you for a field identification; you may provide up to 10 characters to identify the field you are measuring. Next, the program will ask you for the bearing in degrees and the range in meters, of the first measurement; enter these separately when prompted. Next it will ask if this is the end of the data entries. When all measurements for the field have been entered reply Y to this question and the program will calculate the area and the estimated error. You will then be asked if another field area is to be calculated.

Note that when you are asked if the data entries are complete you must answer Y or N, any other response will result in a repeat of the question and a audible "beep"; no harm will be done just give a valid answer and continue.

Method:

Given a field such as



	Bearing a	Range b.
A-B	90	100m
B-C	180	100m
C-D	270	100m
D-A	360	100m

Calculate displacements north (dN) and east (dE)

such that $dN_i = b_i * SIN(a_i)$

$$dE = b_i * \cos(a_i)$$

$$\text{Area} = \sum_{i=1}^{n}\left(\sum_{j=1}^{i} dN_j - dN_i / 2\right) dE_i$$

$$j \leq i$$

The error calculated be this program is the percent difference between the area calculated from the original data (A1) and the area calculated from the same data except that the last set fo range and bearing measurements is adjusted to exactly close the system (A2).

$$\text{Error} = ((A1 - A2)/A2) * 100$$

Where: A1 = Area calculated from data input
A2 = Area from adjusted data

Bibliography

UN/FAO. Some Methods for Calculation of Areas of Polygons Suitable for Pocket and Desk Programmable Calculators, Prepared by P.I. Petricivic, FAO, Rome 1981 (ESS:MISC 81-1).