USAID/IITA MIDAS PROJECT
IN GHANA
Small Farms Systems Research

Terminal Report [1980-82]

International Institute of Tropical Agriculture
Oyo Road, PMB 5320
Ibadan, Nigeria

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IN

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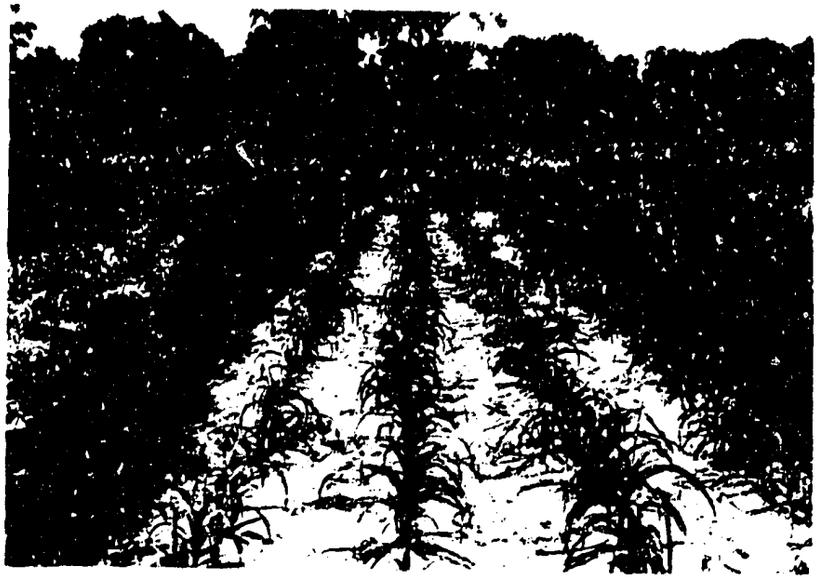
TERMINAL REPORT (1980-82)



Alley Cropping - a possible low input system for Ghana

International Institute of Tropical Agriculture
Oyo Road. Ibadan, Nigeria.

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HIGHLIGHTS OF THE PROJECT

The MIDAS (Managed Inputs and Delivery of Agricultural Services) Project, sponsored by USAID and the Government of Ghana, was designed to improve food crop production and farm income of small farmers in the Brong-Ahafo Region of Ghana. The Small Farms Systems Research is one of six components of the MIDAS Project and was contracted to IITA for implementation. The principal aim of the research component is to assist the Government of Ghana in developing farming systems research capabilities in the Brong-Ahafo Region.

A diagnostic farm-survey of the area was conducted during October to December 1980 to assess the potentials of and constraints to food crop production in the prevailing farming systems. The findings of this survey are discussed in a report entitiled "An appriasal of the present farming systems of the Atebubu District of Ghana" (Balasubramanian et al., 1982)

A farming system research (FSR) model for Ghana has been developed and discussed in section 2 (methodology). Of the six stages in the model, the first two stages on target area selection and diagnostic survey were completed in the present phase of the project. The preliminary result of the studies conducted during 1980-82 are discussed in section 5.

Of the climatic factors, temperature and radiation are fairly adequate for crop production, but rainfall is very unreliable due to high variability and poor distribution. There is a highly irregular sequence of dry and wet years, with no discernible pattern.

The nine-year (1974-82) mean annual rainfall is 1100 mm while the annual values for 1981 and 1982 are 1084 and 692, respectively.

Irregularities in daily rainfall are even larger; the frequent occurence of short term droughts during rainy season and the unpredicted shift in peak rainfall periods cause serious crop failures as happened in 1981 and 1982. The only feasible way to cope with this rainfall pattern is to adopt staggered planting of crops over an extended planting season.

The land form of the area is flat to undulating. The vegetation is typical of the interior savanna (tall grass and open transitional forests) and the soils have developed from the Voltain Sediments. Two important soil (catena) associations found in the area are:

a. Kintampo - Wenchi - Techiman - Ejura - Amantin - Denteso - Sene

b. Nyankpala - Kumayili - Kpelesawgu - Changnalili - Lima - Volta

These soil series have been described and classified and their agronomic suitability and fertility capability have been worked out. Generally upland soils are shallow to fairly deep, poor in organic matter with low inherent fertility and moistrue retention capacity, poor to imperfect subsoil drainage, and high susceptibility to erosion on slopes greater than 5%. On the other hand, the hydromorphic soils found in the lower slopes and valley bottoms are deep, low to medium in organic matter and nutrient contents, poor in drainage and highly susceptible to flooding during parts of the year. Erosion hazard is minimal in lowland soils.

The major causes of soil degradation in the area are exploitation of land without any regard for soil conservation, reduced fallow period and extension of cultivation to highly unstable marginal areas due to demographic pressure, and the present exploitative land tenure system of Ghana which encourages land misuse.

Three land use alternatives to shifting cultivation, viz., (a) high-energy input continuous cropping, (b) agroforestry and other low-input systems and (c) intensified exploitation of valley bottom soils have been described, pointing out the prerequisites essential for their successful operation.

Judicious use of scarcely available fertilizers is very important. Results of fertilizer trials conducted on several crops are briefly summarised.

Yam

Response was mostly up to 30 kg/ha each of N, P_2O_5 and K_2O; at this fertilizer rate, water yam (D. alata) gave 35.5% increase in yield over control as against the 11.9% increase in yield of the white yam (D. rotundata); larger seed yam formation of short season Puna and Labacco (D. rotundata) due to fertilizer use impressed the local yam farmers.

Maize

A rate of 60 to 90 kg N and 30 kg each of P_2O_5 and K_2O per ha seemed to be adequate for a good crop of maize; inclusion of zinc but not magnesium in the above fertilizer schedule may further improve the yield because the interior Savanna soils are deficient in Zn; leucaena leaves compared favourably with fertilizers as a nitrogen source for maize, incorporation and banding of both being better than broadcasting on the surface; split application of leucaena leaves and fertilizers did not give any yield advantage in a low-rainfall year (1982).

Rice

Response was poor to different levels of N,P,K, Mg and Zn fertilizers due to poor management (weed and water control), adverse weather as well as absence of good varieties; local brown rice varieties suffered from blast when high fertilizer doses were used; weed intensity increased with fertilizer use, causing concern among rice farmers who insisted that they need herbicides for weed control before they improve rice yields with fertilizers.

Cowpea

Response was good to the residual effect of fertilizers applied to the previous maize crop; there was a poor yield response to magnesium and trace elements application.

Groundnut

Rhizobium inoculation neither improved nodulation nor did it increase the seed yield of a local groundnut variety "Konkoma", thereby indicating the effectiveness of the native Rhizobium population.

Preliminary results of the leucaena alley cropping trial show that the leucaena grows fairly well in the transition zone of Ghana. The height of the leucaena one year after planting was 261.4 $\pm$ 32.9 cm and the circumfrence at 1 , height was 6.4 $\pm$ 1.7 cm. It can be pruned 4 to 5 times a year. the dry leaf yield being 500 to 1000 kg/ha per cutting.

In the alley cropping trial food crops yields were depressed due to the shade effect of live stakes on yam and competition for moisture between the leucaena and food crops during the frequent dry spells in 1982. There is need for further testing before conclusions are drawn.

In variety testing, preliminary evaluation of several varieties of maize, rice sorhgum, groundnut, and copwea was conducted.

In maize IITA varieties TZSR-W and TZSR-Y were found to be high yielding and at the same time more resistant to maize streak virus attack than other varieties tested. For further evaluation the IITA and CRI varieties with CIMMYT varieties Guanacaste 7729, Los Banos 7622, La Maquina 7843, Poza Rica 7822, Across 7728 and Across 7643 are recommended.

Under lowland rainfall conditions, rice varieties ITA 121, TOX 711 and a local white variety yielded more than 5 t/ha in 1981. ITA 121 failed miserably in 1982 due to very low rainfall and mid seaseson dry spells. Except the short duration Durado Precoce, no other variety performed well under upland conditions, particularly when the drought was severe. Thus there is an urgent need to identify suitable short season and drought-resistant rice varieties for this area.

Grain yields of sorghum varieties were poor due to head mould fungus and insect attact. The degree of head mould fungus infection was related to compaction of the heads, which suggest that sorghum varieties with compact heads are probably not suitable for the Atebubu area. Among top yielding groundnut varieties Florispan Runner was the most consistent. Other good varieties include Mani Pinta, MK 376 and Konkoma. In the International Cowpea Observation Trials, Vita-5 gave the best yield followed by vita-8, vita-4 and TVx 1843-1C.

Yam production management studies on mound size showed that a medium size mound of 1.41m x 1.41m spacing with 5000 mounds/ha gave higher and more profitable yield than farmers' mound size of 2m x 2m spacing and 2500 mounds/ha and was also more profitable than the small size mound with 1m x 1m spacing and 10,000 mounds/ha. This mound size was also better than the farmer' size in reducing yield loss due to nonstaking and late planting as well as in enhancing quicker seedling mergence.

In determining an appropriate method of seed bed preparation for groundnut, ploughing was found to give higher yield of groundnut than ridging but was not significantly different. No-tillage method reduced yield significantly.

Weeds, especially Imperata cylindrica, disease and insect pests are the major problems of crop management in the Atebubu area.

Development of complete packages on crop production and land management was not possible due to lack of time to verfity initial findings in multilocation on-farm testing to formulate packages and validate them at the farm level.

Because the research site selected in 1981 was not accessible throughout the year, in February 1982 a new and permanent site for the research farm was acquired near the Atebubu Training College by the side of the Kumasi-Yeji road. Nearby a meteorological station was established. These two facilities can form a nucleus for the full development of a food crop research farm in Atebubu. Additional facilities to be built are office, field laboratory, storage, and housing for staff.

Throughout the project execution period to counterpart staff was available to work with IITA scientists at Atebubu. There was virutally no progress in the graduate and inservice training of the local staff due to delay in staff recruitment, foreign travel restriction, difficulty in securing admission and general instability in the country. Therefore, whatever progress the IITA scientists have made during the past two and a half years in establishing farming systems research capabilities in the Atebubu area may be lost for want of trained local staff to continue the work after their departure in late 1982.

Major problems encountered during project implementation were (a) delay in the identification of the research site, (b) lack of inputs and research infrastructure, (c) poor linkage with national institutes and absence of counterpart staff, (d) inadequate support staff, (e) poor service conditions including the absence of transport for local staff, (f) short time span and uncertainty about the continuation of the project till the end of the first phase, and (g) inability to train local staff.

Recommendations are given in section 8 on the possible use of data obtained from the 1980-82 studies conducted in the Atebubu area. Two model FSR projects for developing packages on (a) the alley cropping system and (b) cereal-legume cropping systems and their implementation have been discussed. Also provided are the staff and resource requirements for conducting FSR studies in the transition zone of Ghana.

Preliminary findings of the maize fertilizer research and the leucaena alley cropping with yam, maize and cowpea were presented at the annual National Maize Workshops held at the Kwadaso Agricultural College, Kumasi during 1982 and 1983.

1. INTRODUCTION

1.1 Details of the Project

The MIDAS (Management Inputs and Delivery of Agricultural Services) Project is an integrated agricultural development project sponsored by USAID and the Government of Ghana. It is designed to improve food crop production and farm income of small farmers in the Brong-Ahafo Region of Ghana. The Small-Farms Systems Research is one of six components of the MIDAS Project and is contracted to the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The primary aim of its research component is to assist the Government of Ghana (GOG) in developing farming systems research capabilities in the Brong-Ahafo Region. Initially the University of Science and Technology (UST),Kumasi, was to act as the national counterpart organization for the research program; later this role was shifted to the Crops Research Institute (CRI) Kumasi.

IITA provided two scientists - a land management/systems agronomist/ team leader and an agronomist, to work on the project along with national scientists. The two-man team was located at Atebubu from where the project was to be coordinated. One extension specialist was also at Atebubu to work in close collaboration with the researchers. No national scientists were provided to work with IITA team at Atebubu. The implementation of the project started in October 1980.

1.2 General description of the project area

Situated in the central part of Ghana, the Brong-Ahafo Region extends from the Volta Lake on the east to the national border with Ivory Coast on the west; it shares the border with Ashanti and Eastern Regions on South and Northern Region on the north (Figure 1).

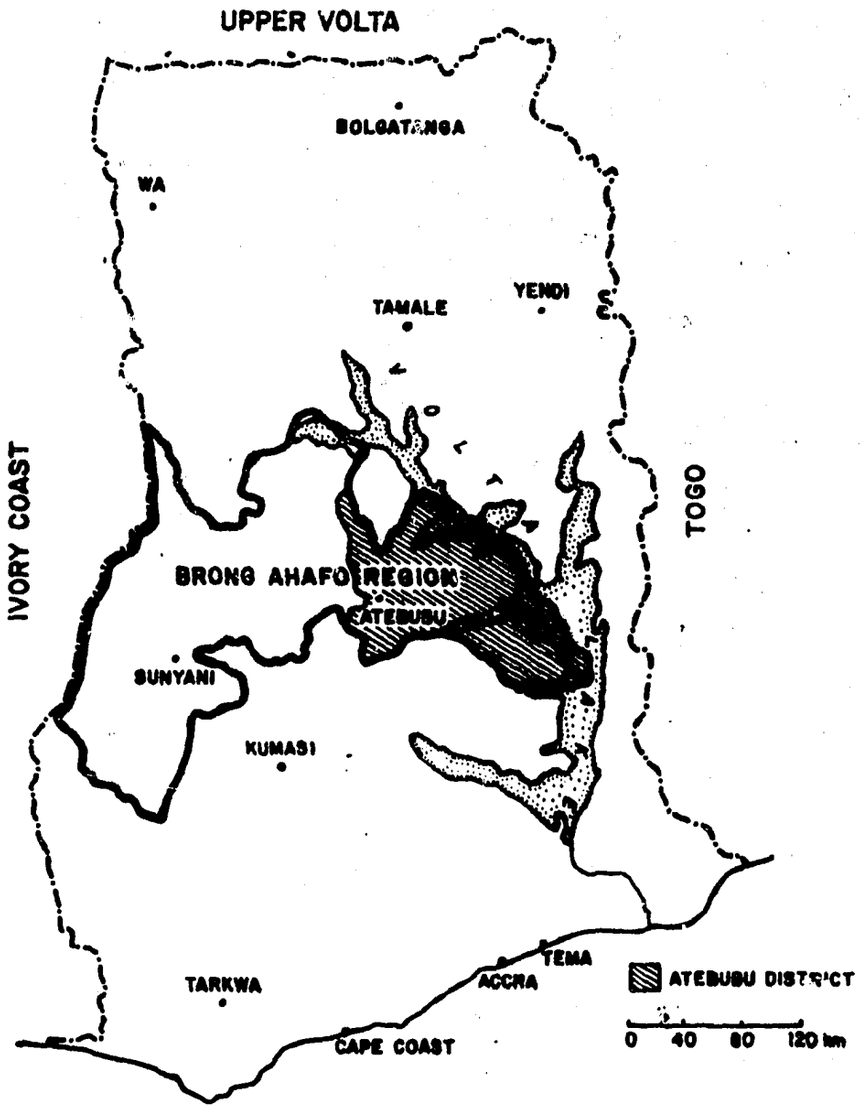


Fig. 1. Map of Ghana showing the location of Atebubu District within the Brong-Ahafo Region.

Atebubu District, where the initial work was undertaken, is the largest of the seven districts in the Region and it occupies the eastern most part. It has a land area of 13,000 square kilometers. The topography of this district is generally flat with the mean elevation less than 150 m above sea level. The mean annual rain-fall is 1,300 mm and the mean temperature is 30°C. The double peak rainfall pattern defines two distinct rainy seasons - major (April to July) and minor (August to October) - with a long dry season starting from mid-November to mid-March. The natural vegetation is typical of interior savanna and consists of open tall grass savanna, savanna regrowth, swamp savanna, riverine thicket, and transitional forest. Most of the soils have been developed from the Voltaian Sediments (fine grained and quartz sandstone, mudstone, shale, conglomerate and pebbles) and they are shallow to fairly deep, medium to well drained and poor in organic matter and plant nutrients.

Atebubu (07° 46'N latitutde, 00° 59'W .longitude, 120 m elevation) is the administrative centre of the district. It is situated on the Kumasi-Tamale road (via Yeji), 400 km from Accra, 150 km from Kumasi and 130 km from Tamale. This district consists of seven subdistricts as shown in Figure 2. The population of the Atebubu District is made up of the Akan-speaking natives and the immigrant northerners (Zongo people). This is the least developed district in the whole of the Brong-Ahafo Region in terms of infrastructure (water supply, electricitity, feeder roads, etc.), rural services (extension, health, machinery and processing); and general transport and market organization.

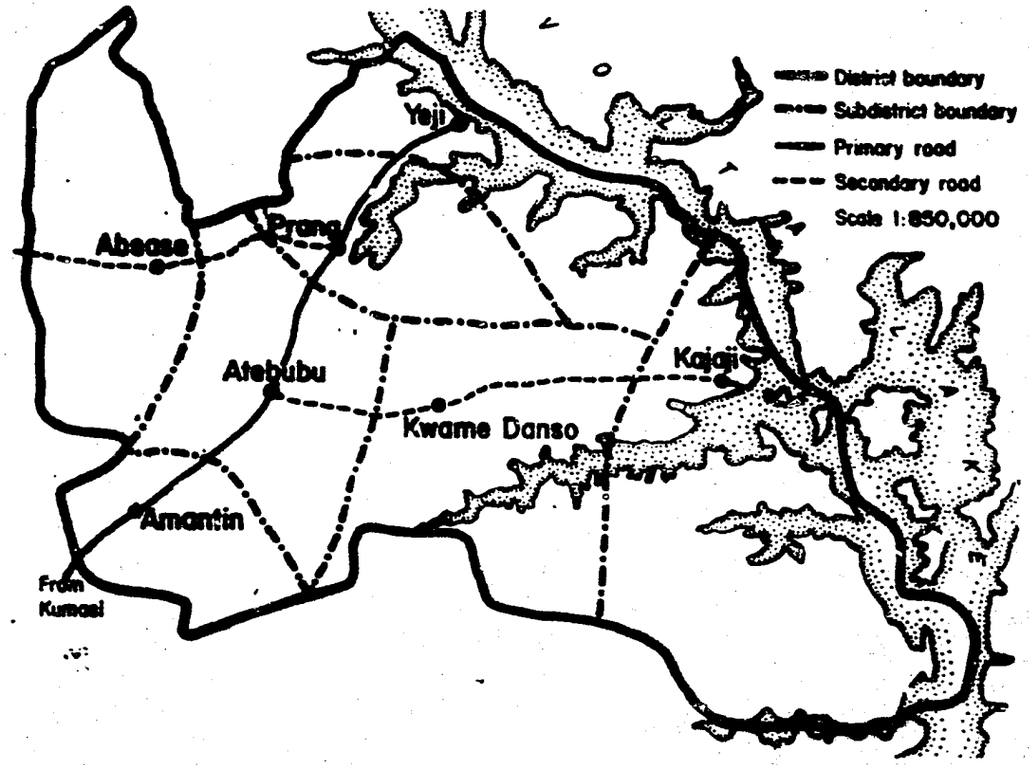


Figure 2. Atebubu district showing the seven subdistricts and headquarters.

1.3 Status of agricultural Development in the Atebubu District

Yam, cassava, maize, rice, guinea corn (sorghum), groundnut and cowpea are the major food crops grown in this district. In addition, several vegetables including African garden egg, tomato, okra, pepper and melon are grown. Plantain, banana and orange, grown mostly in back-yards or compounds, are also produced to a limited extent. Mangoes are usually found growing in wild stands and not cultivated in a regular fashion.

Each of these crops is grown in pure as well as in mixed stands. A farmer's decision to practice sole or mixed cropping usually depends on the nature of the crop, tillage practice, labour requirement and availability and market demand and price. The length of cropping period on a newly cleared land is on average 2 to 3 years for yam based rotation, 3 to 5 years for maize and groundnut monocrops, and more than 5 years for valley bottom rice. Farmers plant yam only once on a newly cleared land. It is also common that cassava is the last crop grown before the land is left under fallow. Fallow periods are generally 5 to 10 years for yam and 3 to 5 years for other crops.

The method of farming in the district can be classified as traditional where simple tools (cutlass, axe, hoe) and human labour are used for land clearing and cultivation although other methods incorporating one or more aspects of modern technology (tractor ploughing, fertilizer use on maize and garden egg, pesticide spray on vegetables) also exist. Some (Government and private) large farms use modern technology in all operations of crop production, mostly for maize and rice.. Livestock is almost entirely absence from the farming system.

1.4 Objectives of the research program

The major objectives of the research program are:

i. To obtain a sound knowledge of the existing farming systems, to socio-economic environment, and their potentials and constraints in the locality serviced;

ii. To conduct relevant applied research that responds to the needs of the small farmers;

iii. To identify soil and farm management and crop production practices that minimize constraints; and

iv. To develop approaches to increase small farmer production and income.

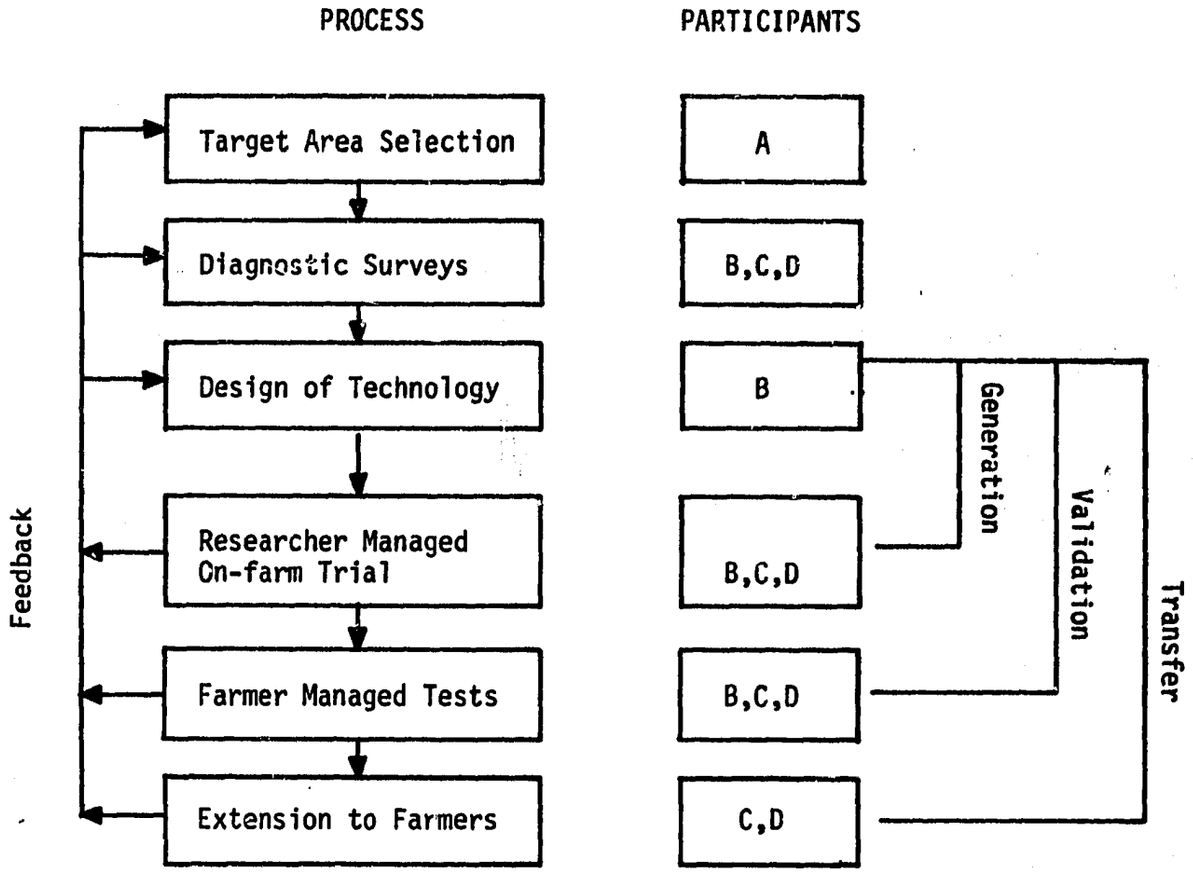
2. METHODOLOGY: FARMING SYSTEMS RESEARCH (FSR) MODEL FOR GHANA

Farming systems research (FSR) emphasises problem diagnosis and on-farm experimentation with a view to develop improved technologies that are likely to be accepted by a majority of the farmers in an area. It is problem-oriented approach in which a lot of activities are carried out on farmer's fields in close collaboration with the extension agents and farmer, as opposed to the discipline-oriented traditional research taking place under the controlled environment of the research stations. FSR compliments the on-station research by speeding up the transfer of developed technologies to the farmers and by drawing researcher's attention to farmer's problems. It is normally carried out by a multi-disciplinary team, technology testing team or on-farm research team, which should consist of at least an agronomist and a social scientist. Additional members from soil science, crop protection, agricultural engineering and other disciplines may be included depending on the type of problem identified in the target area.

The FSR model envisages six stages for the generation, validation and transfer of technology to the farmers (Figure 3). They are described below:

i. Target area - The first step in FSR is to fix the target area in which the program is to be implemented. Most often it is a political decision by a national or regional Government which dominates the selection of a target area. Sometimes technical input from scientists is solicited to decide upon the target area.

ii. Diagnostic surveys - Published information sources and informal surveys are used to gather basic information on farmers' circumstances



A - National or regional decision maker (with or without technical inputs from scientists)

B - Researcher (CRI, SRI, and substations)

C - Extension agent (MOA, GLDB, DEVELOPMENT AGENCIES)

D - Farmers

Figure 3. A Farming Systems Research (FSR) Model for Ghana (Adapted from Schmehl, 1983)

and their present farming systems in the selected area. This may be followed by formal sample surveys to determine production constraints (ecological, economic, institutional and socio-cultural), resource base , labour utilization, product consumption and sale, and market organization. Natural and social scientists as well as extenstion workers should work together as a team in these farm surveys. The information obtained from these surveys will be used to design appropirate technology for the target farmers.

iii. Design of technology - This involves traditional breeding and agronomic research under controlled environment of the research station (CRI and its sub-stations). Technologies imported from outside need to be adapted for local conditions. Both these activities will be necessary to find technical solutions to production constraints identified earlier; while generating new technologies, modest changes rather than abrupt ones in the existing technology should be conceived so that farmers can adopt the proposed changes easily.

iv. Researcher managed on-farm trials - Proposed new technologies are tested using small plots on farmers' fields under various agroclimatic conditions by a multidisciplinary, technology testing team (Agronomist, agricultural economist) in collaboration with the extension workers and the farmer. These trials are managed by the researchers while the farmers provide only land and labour. In these trials non-treatment factors are held as close as possible to the practical farming conditions. They are evaluated for their agronomic and economic superiority over prevalent technology(ies).

v. Farmers' tests - Technologies successfully adapted at the farm level are validated by the farmers in large plots under their own management.

Here the researchers provide the new elements of the technology (seed, fertilizer, etc.) and the farmer has to plant and manage part of his field using the new technology. He then compares the introduced technology side by side with his own and makes his opinion which is an important part of the evaluation. This stage is also known as verification/demonstration in which both researchers and extension workers function as keen observers, constantly monitoring the farmers' reaction to the new technology.

vi. Extension to farmers - The farmer validated technologies are then incorporated into a recommendation and passed on to the extension service for extension to farmers in the target area.

Although the above six stages are listed in a sequential manner, they are not discrete steps. One or more stages can be implemented simultaneously depending on the need and quantum of information and resources available.

Feedback:

At every stage in on-farm experimentation, the unsuccessful technologies are referred back to the research station for further refinement or modification. This feedback ensures a two way communication between researchers, extension workers and farmers.

3. WORK PLAN FOR RESEARCH

To fulfil the objectives listed under section 1.4 and to address some of the food production problems of the Atebubu area identified through diagnostic survey described in section 4.1, a research strategy with the following lines of action was developed.

1. Study of the physical environment
   - Climate
   - Soil resources and their productivity

ii. Soil management
   - Causes of soil degradation
   - Land use alternatives to shifting cultivation
   - Efficient use of fertilizers and manures
   - Biological nitrogen fixation
   - Agro-forestry

iii. Crops and cropping systems management
   - Testing varieties
   - Developing improved production practices

iv. Development of packages for improved soil management and food production

4. IMPLEMENTATION OF THE RESEARCH PROGRAM

4.1 Survey of existing farming systems in the Atebubu District

A farm survey, the second step in FSR, was conducted during October to December 1980, using mainly the group discussion approach; the aim of the survey was to assess the present farming systems of the Atebubu District with regard to their potentials in and constraints to food crop production. The findings of this survey are discussed in detail in a report entitled "An appriasal of the present farming systems of the Atebubu District of Ghana" (Balasubramanian et al., 1982) Completion of this survey fulfils the objective No. 1.4 i of the research program.

The survey report gives a short description of the Atebubu District in terms of agroecology (climate, soils, crops, pests), social system (land tenure, human resources, preferences), rural infrastructure (water supply, electricity, feeder roads, processing and storage facilities, etc.), input supply (fertilizer, pesticide, machinery, spare parts and fuel), rural (extension, credit, health maintainance and repair) services, and general market organization. The major cropping patterns identified are:

i. Yam/maize/cassava relay;
ii. Maize/sorghum relay;
iii. Maize/groundnut or cowpea rotation;
iv. Upland rice/maize relay;
v. Hydromorphic rice (monocrop); and
vi. Garden egg, tomato, okra monocrops.

Major constraints to crop production in this area are as follows:

i. Serious shortage of buldozers, tractors and other machinery and spare parts and maintainance services for them;

ii. Scarcity of modern agricultural inputs such as fertilizers, pesticides, herbicides, etc;

iii. Scarcity and high cost of labour;

iv. Lack of adequate farm credit;

v. Inadequate feeder roads and rural transportation;

vi. Poor processing and storage facilities;

vii. Highly unreliable and poorly distributed rainfall;

ix. Poor soils, erious weed problems, pests.

Solution to constraints i to vi requires suitable changes in the Government agricultural policy and planned action at the national level to encourage small farmer production. In the absence of appropriate action at the Government level, these constraints are difficult to tackle. Suitable technologies should be developed to address the general shortage of inputs supply and labour as well as ecological constraints.

4.2 Generation of technology

In the original plan, it was conceived to establish a research station at Atebubu to undertake applied research on food crop production. Owing to the general economic condition in the country and lack of logistics, this idea was shelved. Even getting permanent research farm was not easy. The site selected in 1980 was not accessible because the approach road was not constructed in time; so a new site was selected for the 1982 season near the Atebubu Training College on the Kumasi - Yeji road.

Improved materials of maize, rice, sorghum, cowpea and groundnut were obtained from the IITA and Institute for Agricultural research (A.B.U.), Nigeria, as well as from the Kwadaso and Nyankpala research stations of the Crops Research Institute in Ghana for testing under Atebubu conditions. Also brought into the country was the leucaena seed for alley cropping.

In addition to trials at the Atebubu research site, researcher managed on-farm trials on yam, maize and rice fertilization as well as on alley cropping were initiated in 1981. The results of these trials and other studies are discussed in section 5.

5. RESEARCH ACCOMPLISHMENTS DURING 1980-82

5.1 Study of the physical environment

i. Climate

A meteorological station was set up near the Training College in Atebubu. The basic instruments installed here will help to measure daily rainfall, windspeed, radiation intensity, maximum-minimum termperature, soil temperature at 5, 10, 20 and 30 cm depths, and relative humidity. Owing to the absence of a trained recorder to make daily observations, full utilization of this facility is yet to be realized.

Temperature, radiation and rainfall are the improtant climatic factors which affect crop growth considerably. Mean monthly temperatures in the Atebubu District range between 21 and 32° which, in general, do not limit crop production. Radiation in this derived savanna zone is better than in the forest area. It is mostly adequate for optimum crop growth in the major season (April - July) but may be lower than crop requirement in the minor season (Agust - October) due to cloudy weather.

Rainfall is the only water source available for agriculture and other activities in the Atebubu District. The mean annual rainfall is 1300 mm, the bimodal distribution of which results in two rainy seasons (April - July and August - October). There is a highly irregular sequence of dry and wet years, with no discernible pattern. The monthly rainfall distribution for the years 1981 and 1982 is compared with that of 1974-82 mean in Figure 4. The mean rainfall for the past 9 years is 1100 mm per annum which is much lower than the long term average value of 1300 mm for this area. In 1981, rains started early in the season encouraging early planting, followed by a dry period in May and an early cessation in October. The major season peak shifted from May-June, to March while the minor season peak occured in August which

is normally a drier month between the two rainy seasons. This abnormal distribution affected both the major and minor season crops seriously in and around Atebubu area. The total amount and monthly distribution of rainfall were below average during 1982 (Figure 4), resulting in a serious water shortage in this area. Crops, particularly cereals wilted severely in both seasons with the consequent reduction in yield; maize and rice failed miserably.

Irregularities in daily rainfall are quite high in this zone. Lesser the total amount per annum,larger is the irregularity in day-to-day rainfall Even during a wet month, a large proportion of the monthly total is received during only a few days. These wet and dry spells are exhibited clearly in the weekly rainfall distribution (Figure 5) for Atebubu. Wet spells encourage erosion due to run off, leaching and waterlogging in the fields. Dry spells cause wilting, particularly on shallow rooted annual crops; this problem is serious in shallow soils which are predominant in this area (plate 1). This short term rainfall variability is highly irregular from year to year and between places within short distances (Figure 5). The distance between Atebub-I and Atebubu-II sites shown in Figure 5 is only 1.5 km, but the difference in weekly rainfall distribution between these two sites is marked.

ii. Soil resources

Detailed soil survey of the research site in Atebubu was completed in 1980 and the report (Adu et. al, 1981) gives an excellent account of the soils found at this site. Reports of other soil surveys conducted in different parts of the district for various purposes can be located in the 1972-73 to 1976-77 Annual Reports of the Soil Research Institute, Kumasi. Report on soil and agrigucltural survey of Sene-Ohosum river basins by

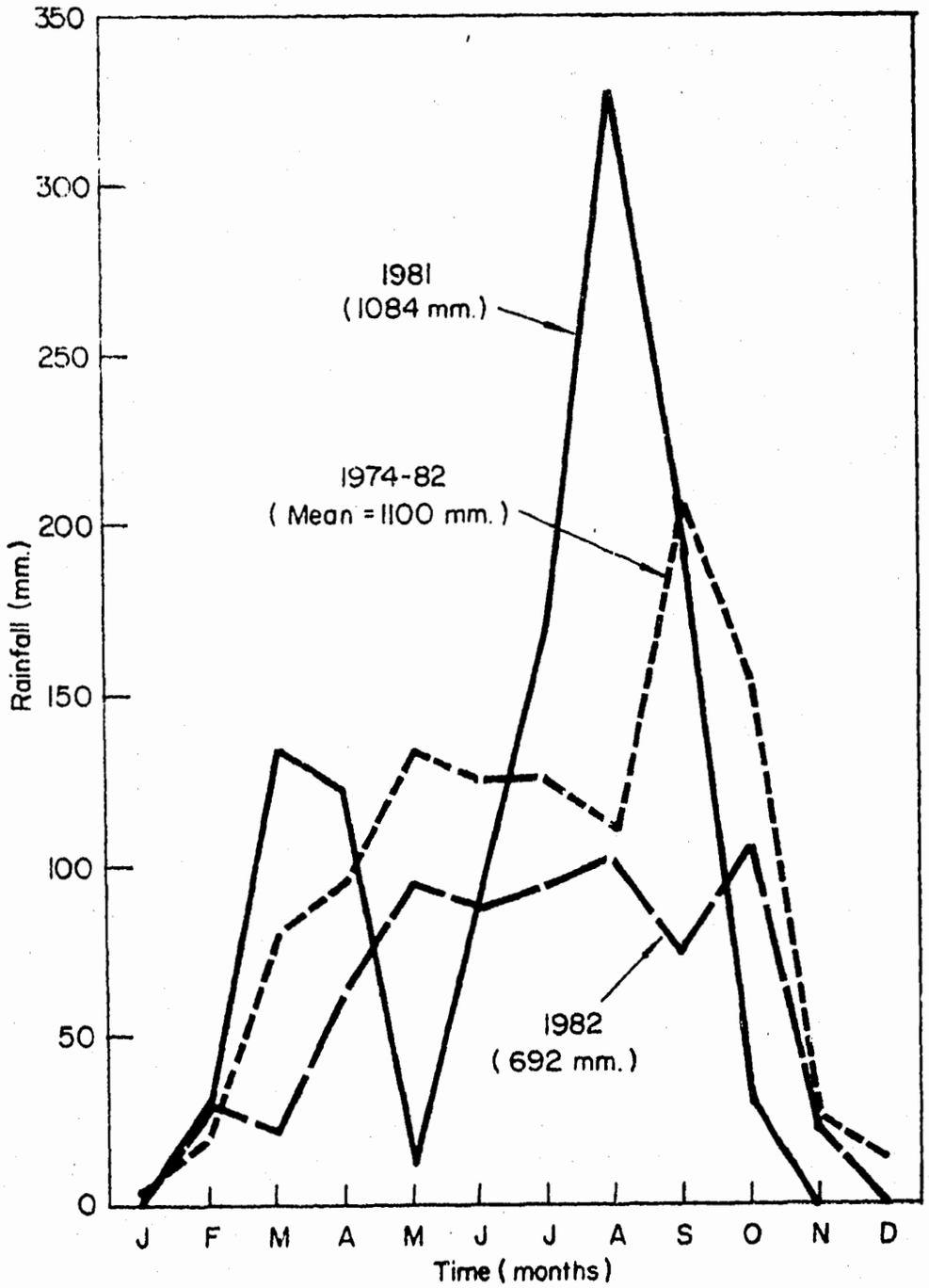


Fig. 4. Monthly rainfall distribution at Atebubu, Ghana.

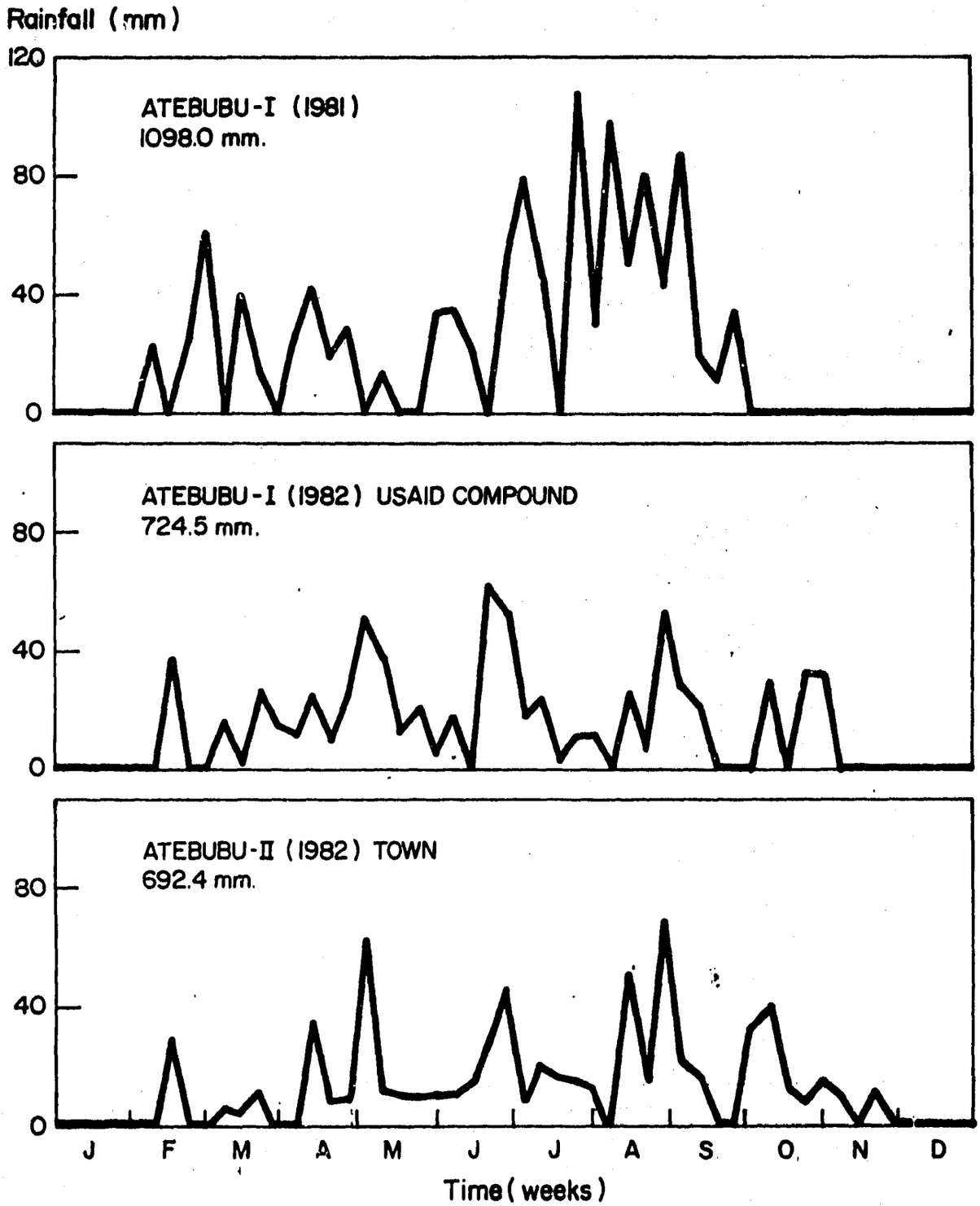


Fig. 5. Weekly rainfall distribution at Atebubu, Ghana.

Plate 1. Severe mid-season droughts affecting crops like this (maize) cause untold hardship to farmers in the Atebubu area.

Smith (1962) also gives valuable information about interior savanna soils.

Most of the soils in the Atebubu District have been developed from the Voltaian Sediments (fine grained and quartz sandstone, mudstone, shale, conglomerate and pebbles) over the lelevation ranging from 50 to 200 m, generally sloping north-easterly toward the Volta Lake. The vegetation is typical of interior savanna and consists of open tall grass savanna, savanna regrowth, swamp savanna riverine thicket and transitiaonal forest as well as cultivated crops.

a. Soil associations: Two improtant soil associations found in this district (Figure 6) are:

A. Kintampo - Wenchi - Techiman - Ejura - Amantain Denteso - Sene catena association; and

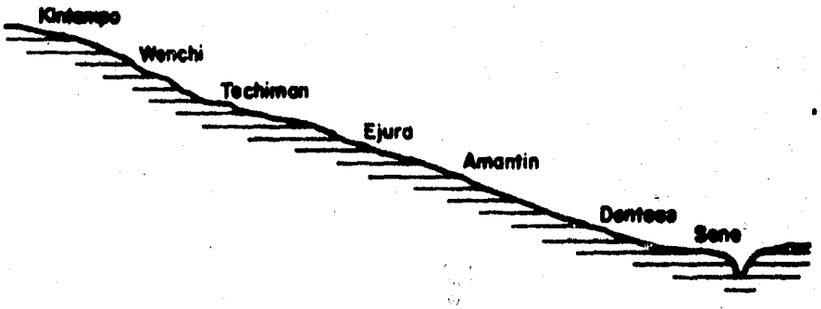
B. Nyankpala - Kumayili - Kpelesawgu - Changnalili Lima - Volta catena association.

Detailed description of the soil series of these two and other minor catena associations is given in 1981 Annual Report of the USAID-IITA-MIDAS Project. A brief description of the above two associations is given below.

A. Kintampo-Wenchi-Techiman-Ejura-Amantin-Denteso-Sene Association

The Kintampo, Wenchi and Techiman series occur on the summits and upper slopes of the catena (Figure 6). These soils have developed from Voltaian Sandstone and are shallow to very shallow in depth. These reddish brown soils, being concretionary or brashy, are susceptible to erosion. They are marginal to poor in productivity. The Ejura, Amantin, Denteso and Sene series, also developed from Voltaian (Obosum) sandstones, are generally deep and their surface soils are free from concretions, gravel or stones. The Ejura and Amantin series occur on the upper and mid slopes and can be easily

A. Kintampo-Wenchi-Techiman-Ejura-Amantin-Denteso-Sene catena association



B. Nyankpala-Kumayili-Kpelesawgu-Changnalili-Lima-Volta catena association

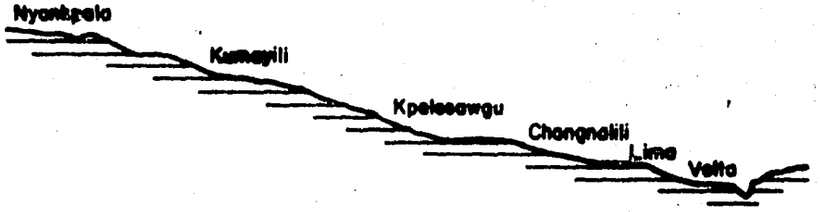


Figure 6. Topographic (catena) sequence of soil series found in the Atebubu District

cleared and cultivated. The Denteso soil is sandy, pale coloured and imperfectly drained and it occupies the lower slopes and valley bottoms. The Sene series is the poorly drained bottom-land member of this association.

B. Nyankpala-Kumayili-Kpelesawgu-Changnalili-Lima-Volta Association

These soils have developed from the mudstones and clay shales. The upland simple association consists of the Nyankpala, Kumayili and Kpelesawgu series while the lowland simple association contains the Changnalili, Lima and Volta series. On the summits and upper slopes occur well drained, moderately shallow, concretionary Nyankpala soils. This is followed by the well drained, fairly deep Kumayili soils and the shallow, imperfectly drained, concretionary Kpelesawgu soils at the mid and lower slopes. On the lower slopes to valley bottoms occur the shallow, poorly drained, gray Changnalili soils, followed by the deep, poorly drained, pinkish gray Lima and Volta soils.

b. Soils classification:

The USDA and FAO classification of all the soil series found in the Atebubu District is given in Table 1. Three orders, viz, Alfisol, Ultisol and Inceptisol are encountered in this area; the Alfisol and Ultisol are found mainly in the upland area whereas the Inceptisol is dominant in the lowland situations.

Table 1. Classification of important soil series known to occur in the Atebubu District.

Soil series	U S D A		F A O
	Family	Subgroup	
Kintampo Wenchi	Very shallow, brashy, isohyperthermic	Lithic Ustorthent	Lithosol
Techiman Nyankpala	sandy, concretionary, isohyperthermic	Oxic Haplustalf	Ferric Luvisol
Ejura (normal & shallow)	sandy, kaolinitic, isohyperthermic	Typic Rhodustult	Orthic Acrisol
Amantin (normal & shallow)	"	"	"
Kumayili (normal & shallow)	silty, mixed, isohyperthermic	Udic Haplustalf	Orthic Luvisol
Kpelesawgu Changnalili	silty, concretionary, isohyperthermic	Typic Plinthaqualf	Plinthic Luvisol
Denteso	silty over sandy, isohyperthermic	Aeric Tropaquept	Dystric Gleysol
Sene	fine over coarse, mixed, isohyperthermic	Vertic Tropaquept	Eutric Gleysol
Lima	Corse-loamy, mixed, isohyperthermic	Aquic Tropaquept	Eutric Gleysol
Volta	clayey over sandy, mixed, isohyperthermic	Aquic Tropaquept	Dystric Gleysol

c. FAO/UN Land Evaluation Criteria for Irrigation (FAO, 1979):

In this system, soils are grouped into seven classes as follows based on their suitability for agriculture:

Class I - Soils that have few limitations for sustained use

Soils in this class are capable of producing sustained and relatively high yields of wide range of climatically adapted crops at reasonable cost. There are few or no limitations of soil, topography or drainage. These soils are level, have effective rooting depth, favourable permeability, texture, tilth, and moisture relations.

Class II - Soils that have moderate limitations for sustained use

The limitations may be due singly or in combination either to gullying (erosion), texture, permeability, moisture availability or effective depth of soil.

Class III - Soils that have severe limitations for sustained use

The severe limitations are due singly or in combination either to wetness, moisture availability, erosion, effective depth of soil, gravelliness or slow intake. These limitations can be corrected.

Class IV - Soils that have serious limitations for sustained use

The serious limitations are moderate to high erosion hazard, steep slope (>5%) or hilly topography, very gravelly or stony texture and very low water holding capacity. Suitable for limited hand and bullock cultivation.

Class V - Soils that are not suitable for sustained use

Severe erosion hazard, steep slopes, excessive drainage, very shallow depth, and stoniness; may be put to perennial crops.

Class VI - Soils not suited for agriculture

These soils are too steep, too shallow, too stony, too droughty, or too wet to be suitable for any cultivation.

Class VII - Non-agricultural lands

e.g., Lagoons, marshes, bovals, scarp phases, and barren lands.

d. Agronomic suitability of the Atebubu soils

The FAO system described above has been used to determine the suitability of the Atebubu soils for agriculture. Their general characteristics and suitability classes are discussed below:

Very good agricultural soils

The Eju ntin and Kumayili series constitute the very good upland agricultural soils for the cultivation of a variety of climatically adapted arable crops. Their characteristics are listed in Table 2. They are moderately deep to very deep (70 to 200 cm), moderately to rapidly permeable, strongly weathered, brown or reddish brown to yellowish red, moderately well to well drained, fine sandy loam to sandy clay loam soils not subject to flooding. They occur on mid to upper slopes, and are thus easy to develop. These soils have satisfactory moisture holding capacity but become droughty during dry spells and dry seaons. Their soil pH is neutral to slightly acidic, exchange capacity is medium to low and inherent fertility is moderate to poor. Application of manures and fertilizers is necessary to produce high crop yields and to maintain soil fertility. Soil management practices should aim at the maintenance of organic matter. Soils with 0-2% slope are included in class 1, with 3-5% slope in class II and above 5% slope in class III. Shallow phases of these series are also included in class III.

The Volta and Sene series are considered very good for the cultivation of swamp rice. They are moderately deep to deep (80-150cm), gray to yellowish brown mottled red, very poorly drained, sandy loam to silty clay loam

Table 2. Characteristics of the very good upland agricultural soils found in the Atebubu District.

Soil Characteristics	Soil Series		
	Ejura	Amantin	Kumayili
Parent material	Sandstone	Sandstone	Mudstone, shale
Elevation, m	150 - 225	135 - 180	120 - 140
Vegetation	Tran./savanna	Tran./savanna	Guinea savanna
Site of occurence	Upper slope	Mid-lower slope	Mid-upper slope
slope, %	0 - 5	0 - 5	0 - 2
Texture			
- surface	Fine sandy loam	F.S. loam	F.S. loam
- subsoil	Sandy clay loam	S.C. loam	F.S. loam
Profile depth, cm	75 - 150	90 - 200	70 - 120
Drainage	Well drained.	Mod.to imperfect	Well drained
Mottling subsoil	No	Yes	No
Water Holding capacity	Medium	Medium	Medium
Permeability			
- surface	Rapid	Rapid	Moderate
- subsoil	moderate	Restricted	Moderate
Erosion			
0-2% slope	Slight	Slight	Slight
3-5% slope	Moderate	Moderate	-
pH	5.8 - 6.8	5.5 - 6.5	6.0 - 6.8
Ex. capacity	low	low	low to medium
O.M. and Nutrients	Moderate	Low-moderate	Low-moderate
Cultivation			
- Mechanical	Good	Good	Good
-Hand	Good	Good	Good
Profile moisture			
-Wet season	Moist	Moist	Moist
-Dry season	Droughty	Droughty	Droughty
Land use class	I to II	II to III	II to III

soils found along the wide, almost flat valley bottoms with slopes less than 1 or 2%. These soils have medium to high moisture holding capacity slow permeability, low erosion hazard, medium exchange capacity and organic matter and nutrient contents (Table 3). They become severely flooded in wet seasons drying to only shallow depths (15 - 25 cm) in the top soil in dry seasons. Sene series differ from Volta soil by having surface textures which are more sandy and subsoil pH which is alkaline due to sodium saturation. Because of heavy texture, mechanical cultivation is advisable. To achieve full potential of these series, water control and provision of drainage will be necessary. They are good for sugarcane and dry season vegetables in addition to swamp rice once water control measures are provided. Moderate fertilizer application to these soils will result in high crop yeidls. They are class III soils.

Good agricultural soils

The Lima and Denteso series are fairly good soils for semi-swamp rice production. They are deep to very deep (90 - 150 cm), pinkish gray to light yellowish brown mottled strong brown, poorly drained, loamy sandy to sandy loam soils occuring on the low-lying lower slopes to wide vallye bottoms (0 - 3% slope). The Denteso soil profle is poorer in clay content and more sandy throughout than the Lima soil profile. Therefore, its nutrient reserve and exchange and moisture retention capacities are very low (Table 3). Both soils become water-logged during rainy seasons and dry out deeply and become droughty in dry seasons. Both soils are slightly acid. The Lima soil is medium in exchange capacity and nutrient contents (Table 3). They are good for both hand and mechanical cultivation and provision of drainage and water control measures will improve their productivity. In addition to rice, sugarcane and vegetables can be grown on these class III soils.

Table 3. Characteristics of the good lowland agricultural soils of the Atebubu District.

Soil Characteristics	Soil Series			
	Lima	Volta	Denteso	Sene
Parent material	Mudstone, shale	Mudsonte, shale	Culluvium sandstone	Alluvium, sandstone
Elevation, m	90 - 210	80 - 120	110 - 150	80 - 150
Vegetation	Savanna	Swamp grass	Swamp savanna	Swamp grass
Site	Lower to bottom	Bottom land	Lower to bottom	Bottom land
Slople, %	0 - 2	0 - 1	0 - 4	0 - 2
Texture				
- surface	Sandy loam	Silty loam	Sandy	Sandy
- subsoil	Sandy loam	Clay loam	Sandy	Clay loam
Profile depth, cm	90 - 150	120 - 150	90 - 120	120 - 180
Drainage	Poor	Poor	Poor	Poor
Water Holding capacity	Medium	High	V. low	Medium
Permeability				
-surface	Moderate	Slow	V. rapid	Moderate
-subsoil	Moderate	V. slow	V. rapid	slow
Mottling in subsoil	Yes	Yes	Yes	Yes
Erosion	Slight	Slight	Moderate	Slight
pH	6.0 - 6.8	5.5 - 6.5	5.4 - 6.4	6.7 - 9.0
Ex. capacity	Medium	Medium	Low	Medium
O.M. & nutrients	Medium	Medium	Low	Low
Cultivation				
- Mechanical	Good	Good	Good	Good
- Hand	Good	Hard	Good	Hard
Profile moisture				
-wet season	sat. 4-5 months	Sat. 4-5 months	sat. 4-5 months	sat. 4-5 months
-drt season	Droughty	Dry surface	Droughty	Dry surface
Land use capability	III	III	III	III

Fair agricultural soils

The Techiman and Nyankpala series, occuring on low summits and upper slopes (0-5% slope), are shallow to very shallow in depth (0-75cm), sandy to sandy loam in texture, brown to reddish brown in colour, and often concretionary in subsoil (Table 4). Erosion hazard is moderately high in these soils, particularly on slopes above 3% . Their water holding and exchange capacities and nutrient status are low and they are often droughty. They are excessively to well drained marginal soils suited mainly for hand cultivation or for the construction of buildings. They are class III soils with more problems than class III lowland soils described above.

Poor agricultural soils

The Kpelesawgu and Changnalili series occupy the low-lying middle to lower slope (0-3%) of the Nyankpala-Kumayili-Changnalili-Volta catena association. These pale gray to light yellow brown soils are imperfectly to poorly drained, concretionary and very shallow in depth to a massive ironpan, which commonly is not indurated unless exposed to the air. They have a very poor plant-soil moisture relationship as they are saturated during the rainy season and very droughty during the dry season (Table 5). These soils need internal drainage but any exposure of the underlying ironpan to air by ditching causes irreversible hardening of the pan, thereby permanently restricting the movement of water in the profile. They are low in moisture and nutrient retention capacities and poor in organic matter and nutrient contents (Table 5). Only hand cultivation is possible in Kpelesawgu soils (class IV) while the Changnalili soils (class VI) should never be cultivated.

Table 4. Characteristics of the fair upland agricultural soils of the Atebubu District.

Soil Characteristic	Soil Series	
	Techiman	Nyankpala
Parent material	Sandstone	Mudstone, shale
Elevation, m	150 - 180	120 - 150
Vegetation	Trans. savanna	savanna
Site	Upper slope to summit	Upper slope to summit
Slope %	0 - 5	2 - 3
Texture		
-surface	Sandy loam	Sandy loam
-subsoil	concretionary	concretionary
Profile depth, cm	45 - 75	0 - 45
Drainage	Excessive	Well drained
Water Holding Capacity	Low	Low
Permeability		
-surface	Rapid	Rapid
-subsoil	Mod. rapid	Restricted
Mottling in subsoil	No	No
Erosion		
-0-2% slope	Slight	Moderate
-3-5%	Moderate	Moderate
pH	5.5 - 6.5	6.0 - 7.3
Ex. capacity	Low	Low
O.M. & nutrients	Low	Low
Cultivation		
-Mechanical	No	No
-Hand	Good	Good
Profile moisture		
-wet season	Moist	Moist
-dry season	Droughty	Droughty
Land use capability	III	III

Table 5. Characteristics of the poor agricultural soils of the Atebubu District.

Soil Characteristics	Soil Series	
	Kpelesawgu	Changnalili
Parent material	Mudstone, shale	Mudstone, shale
Elevation,m	120 - 140	75 - 105
Vegetation	Savanna	Savanna
Site	Mid-to-lower slope	Lower slope
Slope, %	1 - 2	0 - 3
Texture		
-surface	Sandy loam	Sandy clay loam
-subsoil	Concretionary	Pan
Profile depth, cm	0 - 40	5 - 30
Drainage	Imperfect to poor	Poor
Water holding capacity	Very Low	Very Low
Permeability		
-surface	Rapid	Mod. rapid
-subsoil	Restricted	Restricted
Mottling in subsoil	Yes	Yes
Erosion		
0-2% slope	Moderate	Moderate
3-5% slope	Severe	-
pH	6.5 - 7.1	6.0 - 6.8
Ex. capacity	Low	Low
O.M.; nutrients	Low	Low
Cultivation		
-Mechanical	No	No
-Hand	fair	No
Profile moisture		
-wet season	Sat. (3-4 months)	Sat. (3-4 months)
-dry season	Droughty	Droughty
Land use capability	IV	IV

The fact that these sub-marginal soils are very extensive (13,000 to 20,000 square kilometers) in the savanna and transitional climatic zone of Ghana makes it imperative that serious attention be paid to make these soils somewhat productive. At present they are adapted to only poor pasture and grazing.

Soils of the Kintampo and Wenchi series (class VI) are too shallow, too brashy and too droughty to be cultivated.

e. Physical and chemical constraints of the upland soils

Kintampo, Wenchi, Techiman, Ejura, Amantin, Nyankpala, Kumayili and Kpelesawgu series constitute the upland soils. Of these soils, Kintampo and Wenchi series are too shallow, too brashy and too droughty to be cultivated. The profile depths of other soil series are highly variable; Techiman, Nyankpala, Kpelesawgu, Kumayili (shallow) and Amantin (shallow) series are about 60 cm or less in depth while Ejura, Amantin and Kumayili soils are deeper than 60 cm. The surface soil is sandy to silty in texture, grayish brown to dark brown in colour, rapid in permeability and poor in water retention capacity. Surface soil bulk density increases rapidly and available moisture content decreases when these soils are brought under cultivation (Table 6). Owing to the presence of gravel, surface soils of the Nyankpala and Techiman series possess less moisture retention capacity than that of Kumayili, Ejura and Amantin series and therefore crops planted on these soils suffer frequent moisture stresses between rains. Erosion hazard is serious on all upland soils, particularly when slopes exceed 5%. The subsoil is medium fine to fine in texture, yellowish brown in colour, and moderate to restricted in permeability. In the Kpelesawgu and Changnalili series, attempts to improve drainage by open ditches tend to increase the irreversible induration of the subsoil to form ironpan, if this has not already occured (Adu et. al., 1981). Selected surface soil properties of the upland soils are given in Table 7. Generally the upland soils are slightly acidic and low in clay organic matter and nutrient contents as well as exchange capacity. Thus the major constraints of the upland soils to crop production are shallow depth, poor moisture retention capacity, susceptibility to erosion, poor to imperfect subsoil drainage, and low organic matter content and inherent fertility.

Tanle 6: Bulk density and moisture data of two soil series in the Atebubu District of Ghana.

Soil Series	Cultivation Status	Property	Mean	S.D
Kumayili	Bush fallow	Bulk density	1.19	0.06
"	One year after manual clearing	"	1.39	0.07
"	One year after machine clearing	"	1.42	0.04
"	15 years after machine clearing and tractor ploughing	"	1.38	0.01
Kumayili	Bush fallow	Moisture %* F.C.	17.70	1.30
"	"	" " W.P.	3.10	0.38
"	"	Av. moisture %	14.60	-
"	Cultivated for 15 years	Moisture %, F.C.	15.60	0.92
"	" "	" " W.P.	2.53	0.39
"	" "	Av. moisture %	13.07	-
Nyankpala	Cultivated for 15 years	Moisture %, F.C.	13.53	1.12
"	" "	" " W.P.	3.45	0.95
"	" "	Av. moisture %	10.08	-

* Gravimetric mositure %

Table 7: Surface soil properties (mean* and s.d.**) of the upland soils in the Atebubu District of Ghana (Extracted from Adu et al., 1981 and Smith, 1962.

Soil property	Soil Series				
	Nyankpala	Kumayili	Kpelesawgu	Ejura	Amantin
ISDA Classn. Depth, cm	Haplustalf 0 - 18	Haplustalf 0 - 23	Plinthaqualf 0 - 25	Rhodustult 0 - 20	Rhodustult 0 - 26
Sandy, %	67.5*;9.1**	63.3;11.9	62.6	77.0;5.6	72.5;3.5
Silty, %	30.3;6.8	33.6;8.9	35.2	17.9;5.2	22.7;2.8
Clay, %	2.2;2.4	3.1;1.8	2.2	5.1;9.5	4.8;0.7
Moisture % at 0.33 bar	11.0;6.2	11.5;4.1	16.4	-	-
Moisture % at 15 bar	4.4;0.5	3.5;1.3	7.8	-	-
Av. moisture %	6.6;5.8	8.0;4.5	8.6	-	-
pH (water)	6.7;0.4	6.7;0.6	6.8	6.7;0.5	6.4;0.2
pH (KCL)	5.7;0.1	5.9;0.3	5.9	-	-
Org. C,%	0.87;0.57	0.72;0.24	0.85	0.51;0.15	0.43;0.03
Total N, %	0.07;0.01	0.07;0.01	0.08	0.04;0.01	0.03:0.00
C/N ratio	12.01;9.81	9.71;1.63	11.28	14.20;0.58	14.18;0.60
Ex. Ca, me/100g	2.90;04.48	3.01;0.82	4.40	2.21;0.84	1.45;0.65
Mg, "	0.85;0.13	0.82;0.25	1.35	0.68;0.14	0.58;0.03
K, "	0.12:0.06	0.11;0.03	0.08	0.15;0.04	0.09;0.03
Na, "	0.29;0.09	0.23;0.03	0.26	0.18;0.08	0.09;0.10
Mn, "	0.06;0.05	0.07;0.05	Tr	0.13;0.15	0.09;0.10
Total bases, "	4.21;051	4.24;0.96	6.09	3.35:064	2.30;0.56
Ex. acidity, "	0.26;0.11	0.21;0.08	0.19	-	-
ECEC, "	4.47;0.56	4.45;0.93	6.28	-	-
B.S. %	92;3	94;4	97	-	-
Av.P.ppm	2.40;0.85	4.88;1.99	9.30	-	-
Non-ex.K, "	57;20	58;16	31	-	-

f. Physical and chemical constraints of the hydromorphic soils: Lima, Volta, Changnalili, Denteso and Sene series comprise the hydromorphic soils found in the lower slopes and valley bottoms in the Atebubu area. Alluvium, colluvium and shale are the important parent materials forming these soils. They are moderately deep to deep (80-150 cm), poorly to very poorly drained, and loamy sand to silty clay loam in texture. Their surface soil properties given in Table 8 indicate that they have low to medium organic matter and nutrient contents. The erosion hazard is least in these soils. They become severely flooded in wet seasons drying to shallow depth in dry seasons. Because most hydromorphic soils are heavy in texture, mechanical cultivation is advisable. Provision of adequate drainage and flood control will be needed for full exploitation of these soils. Thus, drought in sandy hydromorphic soils, poor to imperfect drainage, the difficulty of controlling floods, and the inadequate fertility are primary obstacles restricting the exploitation of the hydromorphic soils. Inaccessibility and the prevalence of river borne diseases also discourage people trying to farm these soils.

g. Soil Fertility Capability Classification (SFCC) of Atebubu Soils:

SFCC is one of the technical evaluation systems which is very useful to assess the fertility status of soils in a farm (Buol et. al., 1975; IITA, 1979). The SFCC system groups soils essentially according to their fertility limitations, such as texture, effective CEC, pH, potassium deficiency, phosphate fixation, etc. in the surface and subsurface layers. The textural types and condition modifiers are as follows:

Table 8: Surface soil properties (mean* and s.d.**) of the hydromorphic soils (Tropaquepts) in the Atebubu District of Ghana (Source: Adu et. al. 1981 and Smith, 1962)

Soil property	Soil series			
	Lima 0-18 cm	Volta 0-14 cm	Denteso 0-28 cm	Sene 0-25 cm
Sand, %	63.8*;3.8**	37.6;12.0	76.1	72.8
Silt, "	34·3;4.4	53.5;4.9	21.1	26.0
Clay, "	1.9;0.5	8.8;7.4	2.8	1.2
0.33 bar moisture, %	14.4;9.6	21.1;4.9	-	-
15 bar moisture, %	5.0;0.1	8.0;0.2	-	-
Av. moisture, %	9.5;9.7	13.1;5.4	-	-
pH (water)	6.4;0.6	6.2;0.7	5.7	6.7
pH (KCl)	5.4;0.4	4.7;0.1	-	-
Org. C, %	0.87;0.06	0.87;0.08	0.41	0.41
Total N, %	0.08;0.01	0.12;0.02	0.03	0.03
C/N ratio	11.58;0.39	7.60;0.71	14.95	13.20
Ex. Ca, me/100g	3.28;0.74	2.50;0.00	0.89	0.88
Mg, "	0.90;0.42	0.80;0.14	0.31	0.34
K, "	0.16;0.00	0.18;0.13	0.18	0.09
Na, "	0.23;0.00	0.34;0.20	0.12	0.14
Mn, "	Tr	0.03;0.04	0.02	0.01
Total bases, "	4.57;0.16	3.85;0.42	1.52	1.46
Ex. acidity, "	0.38;0.32	0.68;0.67	-	-
ECEC , "	4.95;0.85	4.53;0.25	-	-
B.S., %	92;11	85;14	-	-
Av. P, ppm	4.57;1.16	3.85;0.42	-	-
Non-ex.K, ppm	70;0	58;26	-	-

Textural types (0-20 and 20-50 cm)

S = Sandy, more than 85% sand

L = Loamy, less than 35% clay

C = Clayey, more than 35% clay

R = Root resticting layer in 20-50 cm depth

Condition modifiers (0-50 cm depth)

e = Low effective CEC (Less than 4 me/100)

h = AXidic; pH (water) less than 5.5 and exchangeable Al Saturation 10-45%

a = Aluminium toxicity; exchangeable Al saturation greater than 45%

k = Potassium deficiency; exchangeable k less than 0.15 me/100

i = High phosphorus fixation; P requirement at 0.2 ppm in solution is greater than 350 mg/g

m = Manganese toxicity to most legume crops; pH below 5.0 for high manganese soils

t = Secondary and micronutrient deficiencies (e.g. Mg, S, Zn, B, etc)

w = Low available water reserve (less than 50 mm)

d = Dry, ustic or xeric environment; soils remain dry at 20 to 60 cm depth for more than 60 consecutive days.

r = High erosion hazard

q = Wet, saturated prife during most part of the growing season

f = Iron toxicity in wetland rice

* = Constraints develop from continuous cropping with adequate soil management.

The SFCC system was employed to determine the fertility capability of different soil series found in the Atebubu District of Ghana and the results are shown in Table 9.

Table 9. Soil fertility capability classification (SFCC) of soil series found in the Atebubu District of Ghana.

Soil series	USDA subgroup	FAO classification	S F C C	
			Textural type	Condition modifiers
Ejura) Amantin)	Typic Rhodustult	Orthic Acrisol	LL	e,k,t*,d,w
Kumayili	Haplustalf	Luvisol	LL	k,t*,d,w
Kpelesawgu) Changnalili)	Typic Plinthaqualf	Plinthic Luvisol	LR	e,k,t*,w, d,r,q
Techiman) Nyankapala)	Oxic Haplustalf	Ferric Luvisol	LR	k,t*,w,d,r
Lima	Aquic Tropaquept	Eutric Gleysol	LL	h,k*,t,d,q
Volta	Aquic Tropaquept	Dystric Gleysol	LL or LC	k*,T*,q
Denteso	Aeric Tropaquept	Dystric Gleysol	LL	e,h,k,t,d, w,q
Sene	Vertic Tropaquept	Eutric Gleysol	LL	e,k,t*,q

5.2 Soil Management

i. Causes of soil degradation

As the population pressure builds up, cultivable land becomes increasingly scarce. More marginal land is being brought under cultivation, either in zones of lower or uncertain rainfall or on slopes (Meerman and Cochrane,1982). Additionally the fallow or resting period is shortened as the same land has to be tilled within short intervals by which time the land has not been fully rejuvenated. These practices lead to servere deforestation and serious soil degradation.

Apart from the above general trend, the present exploitative land tenure system of Ghana, in which no one has the right to own the land permanently, encourages land misuse on a large scale. Farmers exploit a piece of land without any regard for soil conservation, move on to another place once the present site is exhausted. Thus, the yearly need to clear new bush is high, thereby continuously increasing the area of impoverished land. Unless, a suitable land reform is introduced in the country, the problem of soil degradation and land misuse will remain as a major bottleneck to increased food production. This problem needs urgent attention by the Government.

ii. Land use alternatives to shifting cultivation

There are three major alternatives to shifting cultivation for increasing agricultural productivity in Africa. They are (a) high-energy input continuous cropping, (b) agroforestry and other low-energy input crop production system, and (c) intensified exploitation of the fairly rich colluvial and valley bottom soils. These systems are briefly described below.

a. High-energy input continuous cropping

It is possible to grow crops continuously on the same piece of land with optimum fertilizer and other chemical inputs, provided adequate soil conservation measures are adopted to protect and maintain soil fertility. Ruthenberg (1980) points out that a small but properly cultivated area most often yields higher returns per hectare and per hour of work than do larger, poorly cultivated or neglected fields. For each hectare of land managed in a highly productive status, there may be less need to clear new bush every year or the extra land can be saved for other conservation purposes such as planted fallow, rotational cropping, etc. Unfortunately, the present practice in Ghana is to tractor plough large areas which are planted and managed very poorly resulting in low yields per hectare. This is especially true for maize and rice. The main draw-back of the high-energy input system is its major dependence on chemical inputs most of which have to be imported from outside. In the absence of assured input supply within the country, as observed in the present-day Ghana, this sytem cannot be successfully operated.

b. Agroforestry and other low-energy input crop production systems

These systems, requiring least amount of imported inputs, are mainly dependent on locally available mineral and renewable resources such as organic wastes, crop residues, legumes, and animal manures. Several strategies are being tried to develop viable low-energy input systems - breeding crop varieties tolerant to soil, pests and weather stresses; legume - cereal rotation in intercropping; managed fallows; and alley cropping or hedge row cropping (Kang et al., 1981; Bandy and Sanches, 1982).

However, the term "low-energy input" does not imply the complete absence of fertilizer use in the system, because in any system there is a need to use some amount of fertilizer input to supply the nutrients deficient in the soil. Most of the low-energy input systems often demand high labour input. The usefulness of the alley cropping system as an alternative to chemical fertilizer use in Ghana has been discussed by Balasubramanian (1983).

c. Intensified exploitation of the valley bottom soils

Colluvial soils in the V-, U- or Saucer-shaped depressions and valley bottoms are fairly rich in organic matter and plant nutrients but poor in drainage. They also suffer from flooding hazard in the rainy season. It dequate drainage and water control measures are provided, these soils can be used for continuous cultivation of sugarcane, rice or rice/dry season vegetable. Since individual farmers cannot build water control measures in these areas due to high initial investment, Government should organize such activities to develop the valley bottom soils. In addition, provision should be made to develop good access to these areas and to control fly- and river-borne diseases. Potentially productive valley bottom soils in the Atebubu District are Lima, Volta, and Sene series which are not fully exploited at present.

iii. Results of fertility trials conducted during 1980 - 1982

Judicious use of fertilizers most often ensures maintenance of soil fertility under continuous cultivation, provided soil erosion is minimal. Fertilizers are usually expensive and often in short supply in most developing countries including Ghana. Increased efficiency in the utilization of available fertilizers is necessary to improve crop yields and over all food production.

During 1981 and 1982, several fertilizer trials were conducted, using yam, maize, rice, groundnut and cowpea as test crops. Except for maize and cowpea, only local varieties were used in these trials. Two Rhizobium inoculation trials on groundnut were executved in 1982. Of the 58 trials listed in Table 10, 20 trials failed due to the low amount and poor distribution of rainfall, harvesting of trials by farmers without informing the researchers, destruction by cattle and ploughing down of the leucaena seedlings by the farmers.

Statistical analysis of the successful trials was carried out using mainly the analysis of variance method. Whereever 'F' statistic was not significant, no LSD was worked out; in such cases only standard error of the mean (SE) is given. Coefficient of variability (C.V.,%) is provided for all the trials.

Detailed discussion of the 1981 results is given in the "1981 Annual Report of the USAID/IITA/MIDAS Project". Detailed discussion of the 1982 results can be found in this report. These results, being preliminary, only indicate trends and need confirmation by repeated trials over time and area. Saliant points emerging from the two-year trials are sumarised here under.

a. Yam response to fertilizer application: Farmers usually cultivate yam on newly cleared land that has sufficient fertility for a good crop. However, fertilizer application may be needed when a piece of land is cropped for a longer period with a rotation involving yam and other crops. This reduces the yearly need for clearing new bush.

Tanle 10. List of trials conducted in the Atebubu District of Ghana during 1981 and 1982.

Crop	Site	Year	Number of Trials		
			Successful	Failed	Total
Soil Management - Fertilizer Use					
Yam	On-station	1981	3	1	4
"	"	1982	4	0	4
Yam	On-farm	1981	9	1 a	10
"	"	1982	4	3 a	7
Maize	On-station	1981	4	1 b	5
"	"	1982	2	2 c	4
Maize	On-farm	1981	2	0	2
Rice	On-station	1981	1	0	1
"	"	1982	0	2	2
Rice	On-farm	1981	3	2	5
"	"	1982	0	6	6
Cowpea	On-station	1981	1	0	1
"	"	1982	2	0	2
Soil Management - Biological N fixation					
Groundnut	On-station	1982	2	0	2
Soil Management - Agroforestry					
Alley cropping	On-station	1981/82	1	0	1
"	On-farm	1981	0	2 d	2
Total			38	20	58

a = Farmer harvested the trial without informing the researcher;
b = Late planted maize failed due to early cessation of rains;
c = Trial was destroyed by cattle;
d = Farmer ploughed down leucaena seedlings.

In 1981 several fertilizer trials were conducted on yam using five different varieties, viz., short season Puna and Labacco and medium duration Dentempruka of white yam (D. rotundata) as well as long season Akaba and Bofi of water yam (D. alata). In a trial with N,P,K, and S, only water yam responded significantly to N and S but not to P and K (Table 11). The response of other varieties was poor. Different N sources gave similar yield responses in all the three yam varieties tested in another trials (Table 12). In many on-farm trials, yam tuber yields increased mostly up to the first level of (30 kg each of N, P_2O_5 and K_2O) fertilizer application; at this level the mean % increase in yield over control was 35.5 for water yam var. Akaba (Table 13) and 11.9% for white yam var. Demtempruka (Table 14). In the case of short season Puna and Labacco, yield increases were observed both during the first harvest of main tubers and the second harvest of seed yams (Table 15.) Seed yams obtained from the fertilized mounds were big and multilobed which can be divided into 3 or 4 units for planting. Because of this response in seed yam, farmers reacted favourably to fertilizer use on yam.

In 1982, fertilizer responses of yam varieties were highly variable and in many cases negative (Tables 16 & 17). The erratic rainfall of 1982 was probably the cause for these poor results. In farmers' fields, the percentage increase in tuber yield for an application of 30 kg/ha each of N, P_2O_5 and K_2O was 64.5, -22.2, 39.8 and 38.7, respectively, for Kokofu I, II and III and Owowam sites (Table 18). Further increase in K level or additon of S and Zn did not give significant response in yield.

Table 11. Yam response to N, P, K and S application at the research site in Atebubu, Ghana, during 1981 and 1982.

Nutrient, kg/ha				Tuber yield, t/ha					
N	P_2O_5	K_2O	S	D. rotundata var. Puna		D. rotundata var. Dendenpruka		D. Alata var. Akaba	
				1981	1982	1981	1982	1981	1982
0	0	0	0	2.88	4.76	3.68	6.66	3.15	9.34
0	60	60	24	2.35	3.73	3.10	3.74	2.90	5.17
30	60	60	24	2.63	4.06	5.33	4.69	5.33	5.23
60	60	60	24	3.93	2.22	5.20	3.07	6.88	5.23
60	0	60	24	4.00	2.77	4.93	5.02	5.63	5.09
60	30	60	24	3.60	4.37	5.58	3.66	6.88	7.65
60	60	0	24	3.98	4.04	2.40	3.93	3.78	4.32
60	60	30	24	2.25	2.88	6.10	4.44	6.23	6.04
60	60	90	24	4.00	3.02	3.00	3.14	5.58	5.89
60	60	60	0	3.58	3.02	4.75	4.44	3.93	9.15
SE				0.95	0.44	1.05	0.89	0.98	1.28
LSD (5%)				-	1.31	-	-	2.93	-
C.V., %				49.8	22.6	41.6	36.2	33.2	34.7

Table 12. Response of three yeam varieties to nitrogen sources at the Atebubu research site in Ghana during 1981 and 1982.

Nitrogen source	Tuber yield, t/ha					
	D. rtoundata var. Puna		D. rotundata var. Dendenpruka		D. alata var. Akaba	
	1981	1982	1981	1982	1981	1982
Control	4.05	4.76	4.03	6.66	6.70	9.34
Am. sulphate	5.95	2.04	4.23	4.60	9.70	8.30
Urea	5.98	2.51	4.03	2.21	7.53	7.31
Cal. Am. Nitrate	-	2.06	-	2.30	-	7.47
15:15:15 Compound	6.33	3.38	2.98	4.65	9.50	7.81
SE	0.83	0.85	0.40	0.51	0.98	1.21
LSD (5%)	-	-	-	1.63	-	-
C.V., %	30.0	68.1	21.0	29.6	23.3	31.3

Table 13. Response of water yam (D. alata) var. Akaba to fertilizer levels at the research site and in two farmers' field in the Atebubu District of Ghana during 1981 (Yield in t/ha).

Nutrient, kg/ha			Research site	On-farm site		Mean (% increase over control)
N	P_2O_5	K_2O	Atebubu	Atebubu	Kokofu	
0	0	0	10.85	8.95	6.08	8.63 (-)
30	30	30	13.48	12.53	9.08	11.70 (35.5)
60	60	60	13.50	10.25	10.00	11.25 (30.4)
SE			0.36	2.28	1.25	-
LSD (5%)			1.06	-	-	-
C.V., %			9.1	37.1	30.1	-

Table 14. Fertilizer response of medium duration white yam (D. rotundata) var. Dentempruka in six on-farm sites in the Akebubu District of Ghana during 1981 (Yields in t/ha).

Site	15;15;15 Compound,kg/ha			SE	C.V., %
	0	200	400		
Afrefreso	7.68	7.98	8.30	1.08	10.7
Kokofu-I	10.15	10.63	14.75	1.75	29.5
Owowam	6.83	8.20	7.63	1.03	26.9
Sanwakyi*	1.78	2.08	2.53	0.38	15.8
Kokofu-II	4.48	4.25	8.13	1.10	44.0
Atebubu	3.75	6.25	5.88	0.60	16.2
Mean	5.48	6.13	7.50	0.45	33.1
% increase over control	-	11.86	36.86	-	-

* Planted late and not weeded; also affected by early cessation of rains.

Table 15. Fertilizer response of short season white yam (D. rotundata var. Puna and Labacco in two on-farm trials in the Atebubu District of Ghana during 1981 (Yields in t/ha).

Nutrient, kg/ha			P U N A			Labacco		
N	P_2O_5	K_2O	Main tuber	Seed yam	Total	Main tuber	Seed yam	Total
0	0	0	5.05	3.33	8.38	2.90	4.83	7.73
30	30	30	9.10	5.00	14.10	3.75	5.15	8.90
60	60	60	9.35	4.85	14.20	4.28	4.85	9.13
SE			0.48	0.60	0.28	0.38	0.65	0.80
LSD (5%)			2.83	-	2.23	-	-	-
C.V., %			8.4	19.5	13.2	20.8	19.5	18.9

Table 16. Yam response to N, P, K and S application at the research site in Atebubu, Ghana, during 1982.

Nutrient, kg/ha				Tuber yield, t/ha		
N	P_2O_5	K_2O	S	D. rotundata var. Puna	D. rotundata var. Dendenpruka	D. alata var. Akaba
0	0	0	0	4.76	6.66	9.34
0	60	60	24	3.73	3.74	5.17
30	60	60	24	4.06	4.69	5.93
60	60	60	24	2.22	3.07	5.23
60	0	60	24	2.77	5.02	5.09
60	30	60	24	4.37	3.66	7.65
60	60	0	24	4.04	3.93	4.32
60	60	30	24	2.88	4.44	6.04
60	60	90	24	3.02	3.14	5.89
60	60	60	0	3.02	4.44	9.15
SE				0.44	0.89	1.28
LSD (5%)				1.31	-	-
C.V., %				22.6	36.2	34.7

Table 17. Response of three yam varieties to N source at Atebubu, Ghana during 1982.

N-Source	Tuber yield, t/ha		
	D. rotundata var. Puna	D. rotundata var. Dendenpruka	D. alata var. Akaba
Control*	4.76	6.66	9.34
Am. sulphate	2.04	4.60	8.30
Urea	2.51	2.21	7.31
Cal. Am. Nitrate	2.06	2.30	7.47
15:15:15 Compund	3.38	4.65	7.81
SE	0.85	0.51	1.21
LSD (5%)	-	1.63	-
C.V., %	68.1	29.6	31.3

* Taken from the adjacent NPKS trial.

Tanle 18. Yam response to fertilizer application four on-farm trials in the Atebubu District of Ghana during 1982.

Nutrient, kg/ha					D. rtoundata			D. alata
N	P_2O_5	K_2O	S	Zn	Labacco*	Dendenpruka		Akaba
					Kokofu-I	Kokofu-II	Kokofu-III	Owowam
0	0	0	0	0	9.77	11.64	10.8	4.10
30	30	0	0	0	14.58	14.47	15.3	6.30
30	30	30	0	0	16.08	9.06	15.1	5.69
30	30	60	0	0	14.59	15.88	17.7	6.15
60	30	0	0	0	19.00	20.93	14.6	7.22
60	30	30	0	0	13.61	12.18	21.1	7.74
60	30	60	0	0	13.34	15.83	16.7	4.88
60	30	90	0	0	10.91	14.48	18.0	6.11
60	30	30	24	0	14.79	13.86	17.2	5.17
60	30	30	24	5	14.62	13.44	15.7	5.16
SE					2.06	2.22	2.6	0.78
C.V., %					20.60	22.20	28.0	26.70

* Labacco tuber yields are total of main tuber plus seed yam.

In short, the two years' data point out that yam response to fertilizer application is mostly up to 30 kg/ha each of N, P_2O_5 and K_2O. Among the types, water yam responds more consistently to fertilizer application than does the white yam.

b. Maize fertilizer trials: Maize is one of the imprtant food and cash crops in the Atebubu District. Low plant population, poor soil fertility, inadequate fertilizer use and poor weed control appear to limit maize yield in this area. In addition to lack of N and P, soils planted to maize are deficient in secondary and trace elements, mainly Mg and Zn .

In Amantin series, maize responded well only to N but not to P, K and S (Table 19); this site has been under maize/groundnut or cowpea cultivation for the past 8 years, each year applying compound fertilizer to the maize crop. In another set of five trials involving K, Mg and Zn conducted during 1981 and 1982, maize response was consistent only to Zn but not to K and Mg (Table 20). A third type of trials tested the maize response to methods and time of application of dried leucaena leaves vs fertilizer at a nutrient level of 90 Kg N and 60 kg each of P_2O_5 and K_2O. Leucaena leaves were applied at the rate of 3,500 kg/ha supplemented that there was no significant difference in N use efficiency by maize given the two sources of N, viz., leucaena leaves and fertilizer.

Incorporation after broadcasting and banding appear to give better grain yields than broadcasting alone both with leucaena leaves and fertilizer. In the case of leucaena leaves incorporation and banding at zero week appear to give better grain yields than at three weeks after planting. Split application of both sources at 0 and 4 weeks after planting did not give any yield advantage.

Table 19. Maize (cv. La Posta) response to N, P, K and S at Amantin, Atebubu District, Ghana, during 1981 (Soil Series: Amantin).

Nutrient, Kg/ha				Grain yield, kg/ha
N	P_2O_5	K_2O	S	
0	0	0	0	1735
0	54	60	24	1997
40	54	60	24	2244
80	54	60	24	2792
120	54	60	24	3087
80	0	60	24	2956
80	27	60	24	2745
80	54	0	24	2611
80	54	30	24	2779
80	54	60	0	2997
SE				102
LSD (5%)				297
C.V., %				12.5

Table 20. Maize yield in response to K, Mg and Zn fertilizer application during 1981 minor season and 1982 major season in the Atebubu District of Ghana.

Nutrient, kg/ha					Grain yield, kg/ha				
					Owowam		Jatozongo		Beks
N	P_2O_5	K_2O	Mg	Zn	1981*	1982	1981	1982	1981
120	50	0	0	0	1639	5137	3207	1154	2670
120	60	0	10	5	1697	4179	3912	1213	3975
120	60	30	10	5	1671	5282	3944	1286	3576
120	60	60	10	5	1964	5462	4267	1439	3953
120	60	90	10	5	1548	4907	4669	1306	3112
120	60	60	0	5	1654	5609	3937	1218	4037
120	60	60	20	5	1756	5337	3592	1413	4245
120	60	60	30	5	1897	4950	4458	1388	3907
120	60	60	10	0	1795	5776	3746	1152	3040
120	60	60	10	10	2190	6077	5092	1480	4498
SE					181	303	274	41	543
LSD (5%)					-	880	794	118	-
C.V., %					20.3	11.5	13.4	6.3	29.3

* Maize cv. La Posta was used in all the trials except the 1981 Owowam trial in which cv. Golden Crystal was used.

Table 21. Effect of method and time of leucaena leaves and fertilizer application on maize yield at Atebubu, Ghana, during 1982 minor season.

Source	Application		Grain yield, kg/ha
	Method*	Time (WAP)**	
Leucaena	B	0	4146
	BI	0	4790
	BD	0	4710
	B	3	4546 Mean = 4416
	BI	3	4229
	BD	3	4596
	BD	0, 4	3897
Fertilizer	B	0	3828
	BI	0	3997
	BD	0	5584
	B	3	4911 Mean = 4716
	BI	3	5109
	BD	3	5557
	BD	0, 4	4025
SE			626
C.V. %			28

* Method : B = Broadcast, Bi = Broadcast and incorporate, BD = Band.

** WAP = Weeks after planting.

c. Rice fertilizer trials: In Ghana, rice is grown mostly under semi-swamp and upland soils under rainfed conditions. Lack of water control, excessive weed problems and low plant population are considered responsible for low rice yields in semi-swamp areas. On the other hand, low productivity of upland rice may be due to lack of nutrients, drought and the use of poor yielding and disease susceptible local varieties, in addition to weed problem. In both years, three rice trials at the research site and 11 rice trials on farmers' fields were conducted. All the eight rice trials - four on fertilizer and four on variety x density x weeding x fertilizer interaction laid out in 1982 failed to produce any worthwhile yield due to poor rainfall. The results from 1981 rice trials show no significant response to fertilizer application, although grain yields increased up to a level of 60 kg N and 30 kg each of P_2O_5 and K_2O per ha. Poor management, especially weed control and lack of water control in the low land sites as well as absence of suitable variety were considered responsible for these poor results. Local brown varieties of rice were found highly suceptible to blast, particularly when N fertilizer was used (Table 22). Weed population also increased significantly with increased fertilizer use on direct sown rainfed rice (Table 22). In fact, the participating rice farmers told us that they do not want to use fertilizers on rice unless they have access to herbicides for weed control.

Table 22. Effect of fertilizer application on weed infestation and blast score on upland rice (Local Brown) at three on-farm sites in the Atebubu District of Ghana during 1981.

Nutrient, kg/ha						Wiase* Weed Score (1-3)	Yeji* Blast score (0-5)	Akyeremade Blast score 0-5)
N	P_2O_5	K_2O	S	Mg	Zn			
0	0	0	0	0	0	1.00	1.00	0.13
30	15	15	0	0	0	1.50	1.00	0.25
60	30	30	0	0	0	1.75	1.62	0.75
90	45	45	0	0	0	2.50	1.62	0.63
120	60	60	0	0	0	3.00	2.38	1.63
120	60	60	24	0	0	3.00	2.88	2.25
120	60	60	24	18	0	3.00	3.25	2.38
120	60	60	24	18	9	2.75	3.38	4.25
SE						0.19	0.32	0.32
LSD (5%)						0.54	0.95	0.94
C.V., %						16.00	30.30	45.50

* These trials were harvested by the farmers without informing us and so we lost the yield data on them.

d. Cowpea fertilizer trials: In 1982, two trials were conducted to evaluate the response of cowpea cv. Vita-5 to Mg, B, Mo and Zn application. Total number of nodules per plant at flowering was not significantly affected by any of the treatments; but the percentage of active nodules was significantly higher in the presence of B than when it was absent (Table 23). Although, the highest yield was obtained when all the elements were applied together, no significant yield response to any particular nutrient was observed.

iv. Biological nitrogen fixation

Rhizobium inoculation trials on groundnut: In 1982, the effect of Rhizobium inoculation on groundnut nodulation and yield was studied at two fertility levels, vz; Farm (no fertilizer application) and High (100 kg/ha each of P and K, 20 kg/ha of Mg and 10 kg/ha of Zn.) The N treatments included were: (a) no nitrogen (control), (b) fertilizer N at 100 kg/ha, and (c) Rhizobium inoculation. These trials were organized in collaboration with NifTAL of the University of Hawaii which supplied the Rhizobium inoculum. The major season trials was sited in a field which had been cultivated for the past 15 years whereas the minor season trial was conducted on a new land cleared from the bush fallow. In both trials, there was no significant response to inoculation in the number of active nodules per plant at flowering as well as in seed yield at harvest (Table 24). On the newly cleared land, High fertility level had a positive effect on nodulation and yield; but fertilizer N application significantly depressed nodule formation, i.e. the number of active nodules per plant.

Table 23. Effect of Mg and trace elements on cowpea (cv. Vita-5) nodulation at flowering and grain yield at Atebubu, Ghana, during 1982.

Nutrient, kg/ha					Nodule number/plant			Grain yield kg/ha	
					Major season		Minor season		
P_2O_5	Mg	B	Mo	Zn	Total	Active as % for total	Total	Major season	Minor season
54	0	0	0	0	11.8	52.0	6.6	1090	1250
54	0	2	1	5	19.9	72.1	8.0	2160	1542
54	20	2	1	5	18.7	80.1	7.2	1410	1516
54	20	0	1	5	13.8	54.7	5.2	1313	1412
54	20	2	0	5	17.6	69.4	7.6	1272	1235
54	20	2	1	0	19.1	66.3	6.8	1180	1011
54	20	2	1	10	18.8	67.8	9.6	1177	1037
SE					3.1	4.6	1.3	86	177
LSD (5%)					-	13.6	-	-	-
C.V, %					35.8	13.8	35.2	13.8	27.5

Table 24. Effect of fertility and inoculation treatments on the number of effective nodules per plant at flowering and seed yield at harvest in Atebubu, Ghana, during 1982.

Fertility level	Nitrogen treatment	Pink/red nodules		Seed yield, kg/ha	
		Major season	Minor season	Major season	Minor season
Farm	Control	1.8	39.2	512	678
"	N, 100 kg/ha	3.5	5.2	615	928
"	Rhizobium	16.8	46.7	583	806
High	Control	0.4	63.2	592	1028
"	N, 100 kg/ha	2.8	17.2	646	950
"	Rhizobium	7.4	52.4	650	938
SE		4.2	10.6	49	71
LSD (5%)		-	32.0	-	214
C.V., %		125.0	57.0	16	16

Such a depressive effect due to N fertilizer use on nodulation was not evident on the cultivated site. The groundnut variety "Konkoma" used in these trials, is capable of nodulating well in Atebubu soils without inoculation.

v. Agroforestry: Alley cropping with Leucaena leucocephala

a. Establishment of the leucaena: Seeds of the leucaena var. K-28 were drilled in continous rows 4m apart in April 1981. They were thinned to one plant every 40 to 50 cm in the row. A starter dose of 100 kg/ha of 15:15:15 NPK fertilizer and 10 kg/ha of zinc sulphate was applied by banding. In 1981 yam, maize and cowpea were planted in the alley space and the leucaena was allowed to grow without pruning. The growth of the leucaena after one year was as follows (mean and s.d. of 135 observations):

Height	=	261.4 ± 32.9 cm
Circumference at 1m height	=	6.4 ± 1.7 cm

During the cropping the season (April to July and mid-August of October) of the second year, the leucaena had to be pruned every six to eight weeks; a total of five prunings were needed per annum. Approximate dry leaf yield per cutting varied from 500 to 1,000 kg/ha. The labour requirement per pruning worked out to be 50 to 60 man-hours/ha.

b. Details of the alley cropping trials: This trial was designed to compare the performance of yam and maize/cowpea in the presence and absence of leucaena hedge rows, 4m apart. The main plots of 20m x 12m were divided into three subplots for fertilizer levels. The split plot design had four replications. The crops will be rotated between plots in alternate years, i.e. the plots which had yam in 1982 will be planted with maize/cowpea and vice versa in 1983.

The arrangement of crops in four representative main plots of one replication is shown in Figure 7. There were four rows of maize or cowpea in the leucaena plots as compared to five rows in plots without the leucaena. The plant spacing in cm was 80 x 25, 80 x 15 and 200 x 200, respectively, for maize, cowpea and yam.

c. Yam tuber yields: The fresh tuber yields of water yam (*Disocorea alata*, cv. Akaba) are shown in Table 25. Unfortunately yields were quite low due to poor rainfall in 1982. The overall effect of the leucaena alley cropping was negative, with an average of 43% reduction in yield. This was mainly due to the shading effects of the live stakes (plates 2 & 3) used for supporting the yam vines, something that has also been observed in experiments at IITA. The leucaena stakes must be ringed before use, so that no new growth takes place to compete with the yam vines for sunlight.

Fertilizer responses with yams were also poor to irregular. The low rainfall was undoubtedly responsible for this failure - at harvest some of the fertilizer applied had not yet dissolved.

d. Maize yields: Maize yields in the leucaena plots were only about half of those in plots without the leucaena (Table 26). This may have been due to the severe competition for moisture between the leucaena and the maize during the many dry spells in 1982 (plate 4).

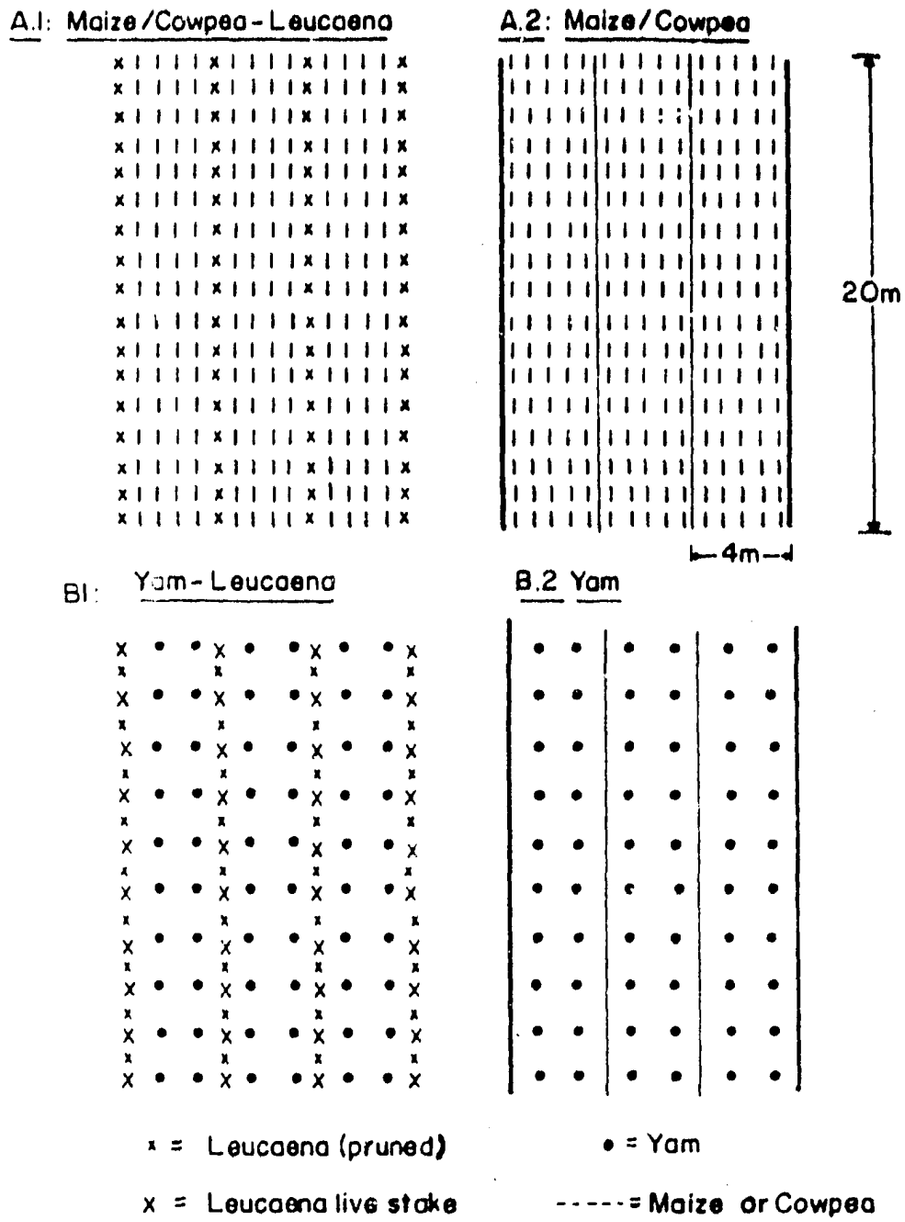
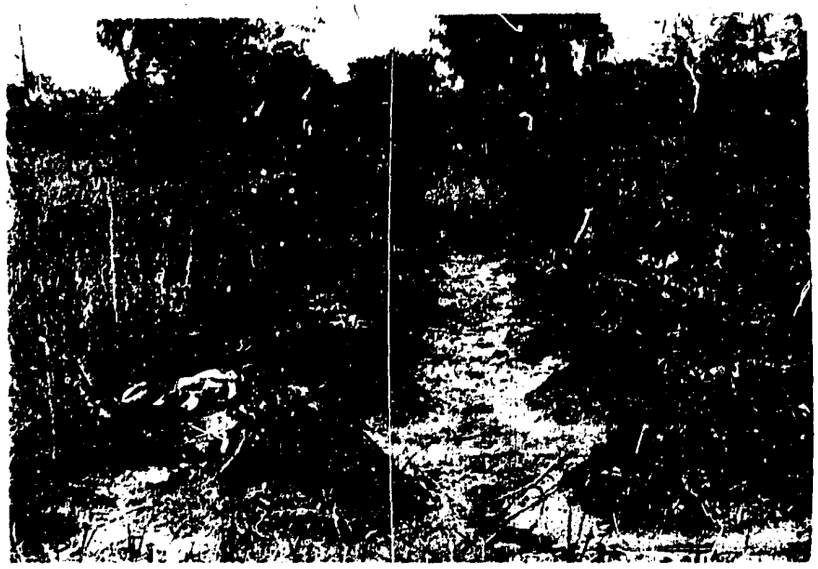


Fig. 7. Arrangement of crops in the leucaena alley cropping trial.

Table 25. Fresh tuber yield of water yam (Dioscorea alata) in the alley cropping trial with leucaena at Atebubu, Ghana, during 1981.

Fert. rate, kg/ha			Tuber yield, t/ha		
N	P_2O_5	K_2O	No Leucaena	Plus leucaena*	Fertilizer mean
0	0	0	9.26	4.53	6.89
30	15	15	6.72	3.87	5.29
60	30	30	8.64	5.52	7.08
SE				0.63	0.45
LSD (5%)				-	1.38
Leucaena mean			8.30	4.64	-
SE				0.55	
LSD (5%)				2.45	

* Leucaena live stakes were used to support yam vines. The shade effect of leucaene live stakes was very pronounced on tuber yield.



A

B

Plate 2. Leucaena alley cropping with yam: A = One week after pruning live stakes; B = Five weeks after pruning, showing the adverse shade effect of live stakes on yam.

Plate 3. The leucaena livestakes shade the yam vines and adversely affect tuber yield. The leucaena stakes must be ringed before use, so that no new leaf growth takes place to compete with yam vines for sunlight.

Table 26. Grain yield of maize and cowpea in the leucaena alley cropping trial at Atebubu, Ghana, during 1982.

Fertilizer, kg/ha			Grain yield, kg/ha		
N	P_2O_5	K_2O	No leucaena	Plus* leucaena	Fertilizer mean
			Major season: Maize		
0	0	0	1886	738	1313
60	30	30	4224	2591	3407
120	60	60	5616	3064	4340
SE			407		288
LSD (5%)			-		887
Leucaena mean			3908	2131	-
SE			398		
			Minor season: Cowpea		
** Residual control			245	120	182
Residual of 60:30:30			465	272	368
Residual of 120:60:60			712	234	473
SE			69		49
LSD (5%)			-		150
Leucaena mean			474	209	-
SE			98		-

* Grain yield in the leucaena plots were calculated on total (80% maize or cowpea + 20% leucaena) area basis and not on equivalent area occupied by maize or cowpea only.

** No fertilizer was applied to cowpea and hence only residual effect of fertilizers applied to maize was measured.

Plate 4. Leucaena alley cropping with maize at Atebubu, Ghana: There is competition for moisture between leucaena and maize during mid-season dry spells.

Maize response to applied fertilizer was highly significant. The interaction between fertility levels and the leucaena treatment was not significant.

e. Cowpea yields: Grain yields of cowpea cv. Vita-5 were low due to poor rainfall and poor insect control. The effect of the leucaena on cowpea yield was very similar to that on maize, the mean yield reduction being 56% (Table 26).

No fertilizer was applied to cowpea. The residual effect of fertilizers applied to maize produced significant increases in grain yield of cowpea. Like in maize, the interaction between fertility and the leucaena treatments was not significant.

f. General comment on the leucaena alley cropping: Owing to the low amount and poor distribution of rainfall in 1982, there was severe competition for mositre between the food crops grown in the alley space and the leucaena (plate 4); yields in the leucaena plots were much lower than in plots without the leucaena. Shading effect of the leucaena livestake (plates 2 & 3) was another cause for yield reduction in yam. This trial has to be repeated for two to three years more to assess the potential of the leucaena alley cropping as a low-energy input system for the transition zone of Ghana.

5.3 Crops and cropping systems management

The improtant food crops grown in the Atebubu district of Ghana are yam, cassava, maize, rice, groundnut, guinea corn (sorghum), cowpea and cocoyam (*Xanthosoma sagittifolium*) melon, okra, pepper and tomato. The dominant cropping system is mixed cropping but sole cropping is also practised especially with maize, rice and groundnut. The cropping cycle differs from one crop to another and so also does the fallow cycle. Two cropping seasons which are described as major and minor season exist. The major season normally begins in April and ends in July and the minor season is from August to November.

The major constraints to crop production in the Atebubu district are lack of improved seeds and appropriate production technology. For this reason research on the crops aspect of the MIDAS research project was designed to select improved varieties of the important food crops and develop improved production practices for use by small farmers.

i. Testing of crop varieties

The objective of variety testing is to evaluate and select crop varieties which are adapted to the Atebubu ecological zone.

During 1981 several crops (maize, rice, sorghum, groundnut and cowpea) consisting of improved varieties and farmer's unimproved varieties were tested to compare yield performance, maturity, disease and pest resistance and other agronomic characters.

a. Maize

Maize is grown by a majority of the farmers since its great demand as food crop makes it a good cash crop. Because most of the maize grown originate from unimproved local seeds, several improved varieties from IITA, CRI and CIMMYT were tested.

The results in Table 27 show that maize yield in the major season was better than that of the minor season. IITA varieties TZSR-W and TZSR-Y outyielded the CRI varieties in the major season. In the minor season TZSR-W had the best yield and TZSR-Y had a lower but not significantly different yield from the CRI varieties. The results (Table 28) of a variety test conducted in collaboration with the CIDA/CIMMYT Ghana Grains Development Project show that with the exception of TZSR-W and Golden crystal which yielded less but not significantly different, the IITA and CRI varieties were as good (5 tons/ha) as the top yielding CIMMYT varieties.

The variety tests further showed that maize crop in the minor season was taller than that of the major season (Table 29), as a result of an early drought in the major season which affected initial crop development. Varietal response to disease and insect attak showed that both TZSR-W and TZSR-Y were more resistant to maize streak virus. However, all varieties were equally susceptible to the stem-borers (*Sesamia calamities* and *Busseola fusca*).

Table 27. Grain yield (kg/ha)[1] of maize varieties tested in major and minor cropping seasons.

Variety	Origin	Major season	Minor season
TZSR-W	IITA	3511	2677
TZSR-Y	IITA	4100	2088
La Posta	CRI	3073	2288
Composite-4	CRI	3032	2380
Golden crystal	CRI	2809	2177
Local white[3]	-	2533	2015
Local yellow	-	3124	2015
Mean		3124	2199
CV (%)		18.5	7.4
LSD (5%)		685	478

[1] Yield is based on 41666 plants/ha

[2] Place where seeds were obtained for testing

[3] Farmer's unimproved variety.

Table 28 Grain yield of some international maize varieties tested at Atebubu in the major cropping season.

Variety	Origin	Maturity (days)	Grain yield[1] (tons/ha)
TZSR-W	IITA	120	4.47
TZSR-Y	IITA	120	5.51
La Posta	CRI	120	5.33
Composite 4	CRI	120	5.14
Golden Crystal	CRI	110	4.31
Composte W	CRI	120	5.85
Early yellow	CRI	100	3.16
Suwan 1	Thailand	110	3.95
Suwan 2	Thailand	100	3.54
Guanacaste 7729	CIMMYT	118	5.27
Los Banos 7622	CIMMYT	118	5.84
La Maquina 7843	CIMMYT	120	5.81
Poza Rica 7822	CIMMYT	118	5.78
Seleccion Precoz	CIMMYT	95	3.20
Perke 7526 (1)	CIMMYT	110	4.09
Across 7728	CIMMYT	118	5.26
Across 7729	CIMMYT	118	4.70
Across 7643	CIMMYT	120	5.70
TL 7621 DN	CIMMYT	110	4.81
Delhi 76221 (1)	CIMMYT	118	3.60
Mean		114	4.77

Grain yield: CV (%) 20.5 LSD (5%) 1.61

[1]Yield based on 50000 plants/ha.

Table 29. Growth parameters and virus streak incidence of maize varieties planted in the major and minor seasons.

Variety	Major season			Minor season		
	Plant height (cm)	Days to 50% silking[1]	Streak virus incidence (%)	Plant height (cm)	Days to 50% silking	Streak virus incidence (%)
TZSR-W	164	-	1.5	202	64	2.4
TZSR-Y	165	-	0.8	185	62	3.4
La Posta	163	-	12.4	189	67	3.8
Composite-4	174	-	6.5	217	65	3.9
Golden crystal	163	-	4.4	189	63	1.5
Local white	180	-	2.0	203	62	3.1
Local yellow	163	-	2.2	188	58	4.4
Mean	167	-	4.2	196	63	3.2
LSD (5%)	14	-	3.6	22	3	n.s

[1]Data not collected during major season.

b. Rice

Ten promising rice varieties from IITA together with one variety from CRI and two farmer's local varieties were tested under rainfed conditions on hydromorphic soil. A similar trial under upland conditions failed due to inadequate rainfall and drought. The yield results (Table 30) show that ITA-121 with a moderate height and excellent tillering ability had the best performance with a grain yield of 5.43 tons/ha, followed by TOX 711 with 5.38 tons/ha. Other varieties with high yield performance were ITA-212, ITA-123 and the farmer's local white (long grain) variety which had 4.63, 4.49 and 5.08 tons/ha, respectively.

The local white seems to be a high yielding variety but its long growth period and strong tendency to lodge pose severe limitations on its desirability. Duorado precoce, a poor tillering short duration Brazilian variety from CRI had the lowest yield. All varieties except TOX-711, Duorado precoce and the local white showed symptoms of brown spot disease.

c. Sorghum

The predominant sorghum (Guinea corn) varieties grown in the area are the red and white seeded, long season, tall varieties with open heads. In testing for suitable varieties which are high yielding and of short season, several sorghum varieties of short to medium height and growth duration from the CRI substation at Nyankpala and from Nigeria were evaluated along with the tall local varieties.

Most of the introduced varieties suffered head mould fungus attack due to their large compact heads, which results in low grain yield (Table 31). The degree of infection which seemed to be related to compaction of the heads suggests that varieties with compact heads are not suitable for the more humid transitional zone of the Atebubu area.

Table 30. Height, maturity and grain yield of rice varieties tested.

Variety	Height (cm)	Maturity (Days)	Grain yield (kg/ha)
ITA-116	106	110-120	3658
ITA-117	90	110-120	2518
ITA-118	104	110-120	2146
ITA-119	88	110-120	3487
ITA-121	90	120-130	5433
ITA-123	95	120-130	4486
ITA-135	135	110-120	2912
ITA-162	128	115-125	3108
ITA-212	99	120-130	4625
TOX 711-59	96	125-135	5375
Duorado Precoce	118	85-95	1984
Local white	140	135-145	5079
Local brown	136	120-130	3283
Mean	109	115-125	3700

LSD (5%) : Grain yield 1156.

Table 31. Height, grain yield and pest and disease score of sorghum varieties.

Variety	Origin	Plant Height (cm)	Grain yield (kg/ha)	Stemborer damage (%)	Head mould score[1]
5-24	Nyankpala	141 d	1095 c	13.6	3
7-168	Nyankpala	107 b	440 a	0.6	5
11-215	Nyankpala	86 a	434 a	1.8	4
19-50	Nyankpala	118 bc	518 a	10.1	4
26-196	Nyankpala	140 d	830 abc	0.6	3
28-78	Nyankpala	134 cd	487 a	5.4	3
LS-1499	Nigeria	116 bc	696 abc	-	-
LS-187	Nigeria	114 b	478 a	0.6	5
KBL	Nigeria	122 bcd	1030 bc	8.9	2
H P-3	Nigeria	106 b	675 ab	1.8	4
Local red	-	309 e	1059 bc	7.1	0
Local white	-	374 f	1062 bc	10.1	0

Means followed by the same letter in the same column are not significantly differenct at 5% level of Duncan's Multiple Range Test.

[1]Scores from 0 to 5; 0 = no visible symptons; 5 = very severe sysmptons.

Nyankpala variety 5-24 had the best yield performance with 1095 kg/ha followed by the two local varieties with 1062 kg and 1059 kg/ha respectively. The Nigerian variety KBL (Kano Bulk Line) had the fourth highest yield with 1030 kg /ha which was not significantly different from that of the highest yielding variety.

Stand damange by the sorghum stem borer (Busseola fusca) caused serious lodging problems especially on the local varieties as well as on Nyankpala varieties 5-24 and 19-50, and Nigerian variety KBL. Sorghum mite attack reached a serious level on Nigerian variety LS-187.

d. Groundnut

Groundnut (Arachis hypogaea) is a good source of protein in the diet of the people as well as an improtant source of income for small farmers. In testing for adaptability, several groundnut varieties from the CRI field station at Ejura as well as from Nigeria were evaluated along with the local variety (Konkoma) grown by most farmers.

The test results (Table 32) show that groundnut pod yields were higher in the major season than in the minor season, except for Spanish 205 and Natal Common which yielded better in the minor season. Also, the yields were not significantly different for most varieties. The best variety however, was Mani Pinta which had a significantly higher yield than other varieties. Owing to its high oil content and poor taste this variety is only suitable for the vegetable oil industry. MK374, the second highest yielding variety in the major season, had low yield in the minor season due to poor seed germination. Other varieties with good performance are Florispan Runner, which maintained high yields in both cropping seasons, Konkoma and shitochi.

Most varieties matured within 90 - 100 days after planting but the long duration varieties, Mani Pinta and MK 374, required 120 - 130 days. Kumawu which seemed to have no dormancy period and which germinated even before it was harvested, was the earliest variety.

Table 32. Pod yields (kg/ha) of groundnut varieties tested in the major and minor cropping seasons.

Variety	Origin	Major season	Minor season
MK 374	Nigeria	2536	1290
Spanish 205	Nigeria	1420	1682
Mani pinta	Ghana	3929	-
Kumawu	Ghana	1720	1461
Konkoma	Ghana	2113	1519
Natal common	Ghana	1410	1571
Florispan runner	Ghana	2276	2109
Shitochi	Ghana	-	1957
Mean		2201	1656
CV (%)		30	25
LSD (5%)		798	495

d. Cowpea

Cowpea is not widely grown in the Atebubu district because of the difficult pest management problem associated with it. As a result only a limited number of farmers grow it using unimproved local seeds.

In an initial screening test, 30 cultivars of erect and semi-erect types of IITA's cowpea selected for international testing and two local varieties were evaluated for yield performance. Thirteen of the 32 entries had grain yields more than 1000 kg/ha. Among the high yielding entries (Table 33) Vita-5 had the best result with 1716 kg/ha followed by Vita-8 (1689 kg/ha), Vita-4 (1602 kg/ha) and TVx 1843-1C (1447 kg/ha) The local varieties had low yields but were slightly better than some of the international cultivars probably because of better adaptation to the local environment.

Table 33. Yield (kg/ha) trial of International cowpea cultivars[1].

Entry	Cultivar	Yield	Entry	Cultivar	Yield
1	Vita 3	-	17	Vita 4 L.S. 2-1	1312
2	Vita 4	1602	18	Vita 5 L.S. 7-1	1250
3	Vita 5	1716	19	Vita 5 L.S. 11-1	1012
4	Vita 7	959	20	Local check (white)	750
5	Vita 8	1689	21	Vita 6	900
6	TVx 1850-01E	944	22	4R-0267-1F	677
7	TVx 1948-01F	199	23	TVx 309-1G	948
8	TVx 1999-02E	-	24	TVx 1836-013J	724
9	TVx 2912-03J	1358	25	TVx 2394-02F	-
10	TVx 2949-03J	1219	26	TVx 2724-01F	605
11	TVx 3040-01E	1255	27	TVx 3072-01E	522
12	TVx 3356-04F	853	28	TVx 34-4-01E	425
13	TVx 3380-042E	960	29	TVx 3428-03E	584
14	TVx 3381-02F	1239	30	Local check (brown)	559
15	TVx 3405-01E	972	31	Vita 5 L.S. 3-3	1027
16	TVx 3410-05D	1058	32	TVx 1843-1C	1447

[1]Entry 1, 8 and 25 had poor seed viability.

ii. Improved production practices

The development of an improved production practice permits the genetic potential of a crop to be realized, thereby optimizing crop yield and maximizing economic return. The method of growing yam in mounds was studied to determine the most suitable mound size that could give the farmer a maximum return in terms of yield and overall economic gain. Similarly, different methods of seed bed preparation for groundnut were tested to determine the method that gives optimum groundnut yield.

a. Yam mound size studies

Atebubu district is the centre of yam production in Ghana, where a wide variety of yams of different forms, shapes and sizes abound. Yams are traditionally grown in large mounds which are approximately 75 cm high and 160 cm in diameter with an average spacing of 2m between mounds. The making of such large mounds is labour intensive and the very wide spacing limits the number of mounds that can be made in a given field.

(1) Effect of mound size and mound population density on yam yield

Normally a farmer could increase production by clearing more land for more mounds which results in higher labour cost. However, instead of clearing more land he could increase the mound population within a given field by reducing mound spacing, thereby reducing mound size.

In a study to determine yam response to different size mounds at two mound populations, three mound sizes including that of the farmer were tested.

Mound size development

Based on the average spacing of 2m between mounds as observed on farmers' fields, three mound sizes were selected and made by gathering surface soil from 2m x 2m, 1.41m x 1.41m and 1m x 1m areas to form corresponding large medium and small mound sizes, with approximately 75 cm, 54 cm and 35 cm height and 160 cm, 100 cm and 75 cm base diameter, respectively.

Table 34. Effect of mound size on yam tuber yield and average tuber size.

Mound size	Tuber yield (kg/mound)	Tuber size (kg/tuber)
Large	3.64	1.62
Medium	2.87	1.50
Small	1.98	1.11
LSD (5%)	0.59	0.32

Mound population:

Two mound populations consisting of a fixed number or a variable number were tested. In a fixed population the number of mounds per plot was independent of mound size and the spacing between mounds was fixed at 2m. In the variable population the number of mounds varied according to the specified spacing for each mound size (Figure 8), so that the number of mounds per hectare were 2,500 5,000 and 10,000 for the large, medium and small size mounds, respectively.

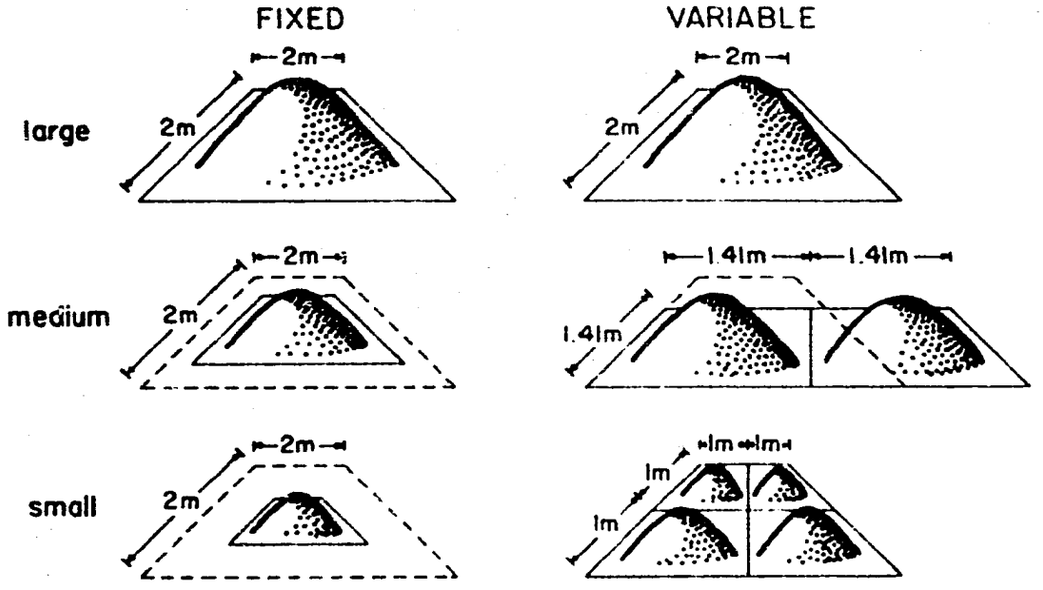


Fig. 8 Fixed and variable mound population layout for large, medium and small mound sizes.

Yam tuber yield:

The effect of mound size on yam tuber yield was related to the volume of tilled soil available for tuber development. Hence, the larger the mound size the larger was the tuber size i.e. tuber weight as well as tuber yield per mound (Table 34). Therefore at a fixed mound population total yield per hectare was directly related to mound size. However, when the number of mounds per plot varied according to the specified mound spacings the total yield per hectare increased with reduction in mound size. Therefore, the small mound with the largest population had the highest total yield (Figure 9).

These results thus indicate that a farmer could increase production by reducing mound size to accommodate more mounds without the necessity for clearing more land.

(2) Effect of mound size, staking and variety on yam tuber yield.

Staking is normally practised but where stakes are short supply some of the yams are usually left unstaked. Farmers believe that there is no difference in yield between staked and nonstaked yams. To verify if by allowing for unrestricted tuber growth the large size mound often used by farmers could compensate for the expected loss in yield due to nonstaking, a study was conducted to determine the response of yam to different size mounds with and without staking. Using two popular yam varieties, white yam. (*Dioscroea rotundata*, cv. Dentempruka) and water yam (*Dioscorea alata*, cv. Akaba) with similar size mounds and spacing as in the previous experiment, half the number of yams planted in each plot were staked in a split-plot design.

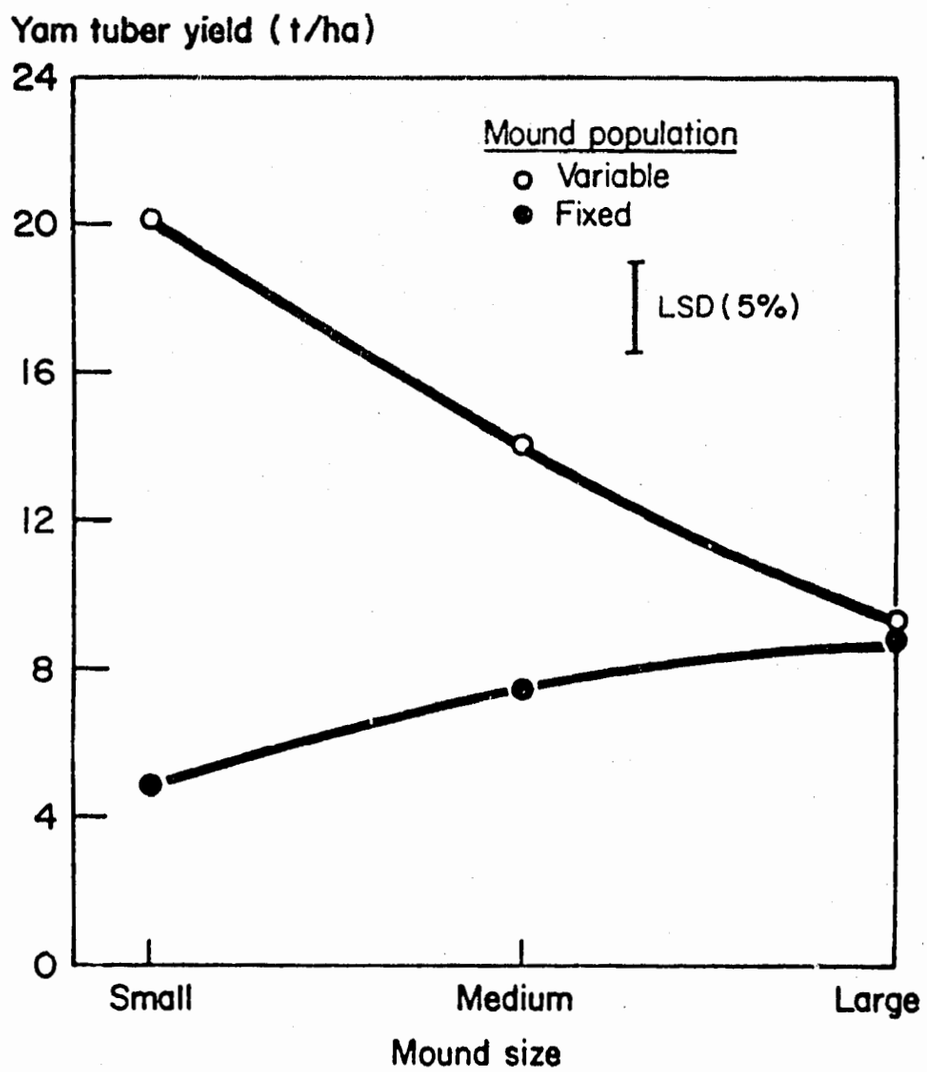


Fig. 9. Effect of mound size and mound population on yam tuber yield.

Yam response

Staking gave higher yields than nonstaking expecially with D. rotundata in which tuber yield was significantly reduced by nonstaking (Table 35 and plate 5). With D. alata tuber yield in general was not much affected although when planted in large mound it suffered greater depression in yield due to nonstaking (Table 36), which indicate that the large size mound probably enhanced yield loss rather than reduce it when yams were not staked.

Table 35. Effect of staking on tuber yield (kg/mound) of yam varieties[1].

Variety	Staking	No staking	Mean
D. rotundata	3.78	3.07	3.42
	(0)	(-18.8)	(-9.4)
D. alata	3.30	5.08	5.19
	(0)	(-4.3)	(-2.1)
Mean	4.54	4.07	
	(0)	(-10.0)	
CV (%)	13.4		

LSD (5%)

Staking means = 0.24

Staking within variety = 0.34

[1] Numbers in parenthesis are % yield loss (-).

Plate 5. Effect of staking and no staking on yam (Dioscorea rotundata) tuber yield.

The results also show that the magnitude in yield loss could be reduced by decreasing mound size due to the accompanying reduction in tuber size. Hence, a smaller loss in yield was obtained in the medium size mound than in the large mound. This trend however, did not continue with the small mound because its shallow depth which restricted tuber development resulted in greater yield loss than that of the medium size mound. Nevertheless, these observations show that by selecting an appropriate mound size yield loss due to nonstaking could be reduced.

Table 36. Effect of mound size and staking on tuber yield (kg/mound) of yam varieties.

Mound size	Variety	Staking	No staking	% Yield loss
Large	D. rotundata	5.39	4.03	25.2
	D. alata	7.88	7.04	10.7
	Mean	6.63	5.53	17.9
Medium	D. rotundata	3.32	2.95	11.1
	D. alata	4.91	5.08	-3.4
	Mean	4.12	4.02	3.9
Small	D. rotundata	2.63	2.23	15.2
	D. alata	3.11	3.08	1.0
	Mean	2.87	2.65	8.1
	Mean	4.54	4.07	
	CV (%)	13.4		

LSD (5%) Staking means =0.24
Staking within variety and mound size = 0.59
Staking within mound size = 0.41

(3) Effect mound size, planting date and variety on yam tuber yield and seedling emergence

Although farmers usually grow yams in large mounds, sometimes during late planting they may choose to use smaller size mounds probably to encourage quicker seedling emergence, thereby compensating for lost time. To determine the effect of such practice on yam tuber yield and seedling emergence two varieties of yam were grown in differenct size mounds planted on different dates. Using the three mound sizes and spacing as in previous studies, planting was begun with the first rain towards the end of February and continued at one month interval until the end of April.

Effect on tuber yield

The results (Table 37) show that the longer the delay in planting the smaller the yield was. This means as the growing period got shorter the loss in yield became greater. The response with respect to mound size shows that the large mound had the greatest loss in yield which increased from a 5% level of significance after one month to a 1% level after two months. In comparison the yield loss suffered by the medium size mound was significant at the 5% level only after two months delay in planting while that of the small mound was not at all significant even after two months.

The varietal response pattern showed that white yam suffered a significantly greater loss in yield than water yam when planting was delayed until April. Water yam is always the last variety of yam harvested by farmers and for this reason it is sometimes planted even as late as May.

Perhaps this planting practice could also be explained by the fact that it is less affected by late planting.

These results thus show that to obtain good yield in yam production, especially with D. rotundata early planting is essential. However, if planting is delayed the choice of an appropriate mound size of a smaller nature than the normal size could minimize yield loss.

Table 37. Effect of mound size and planting date on average tuber yield per mound (kg)[1].

Mound size	Planting date			Mean
	Feb. 26	March 29	April 30	
Large	2.74	1.91	1.66	2.10
	(0)	(-30.3)	(-39.4)	(-23.2)
Medium	2.44	1.96	1.65	2.01
	(0)	(-19.4)	(-32.4)	(-17.4)
Small	1.63	1.60	1.06	1.43
	(0)	(-1.8)	(-34.6)	(-12.2)
Mean	2.27	1.82	1.46	
	(0)	(-17.3)	(-35.6)	
CV (%)	28.9			

LSD (5%):
Planting date means = 0.37
Planting date within mound size = 0.64
Mound size means = 0.37

[1]Numbers in parenthesis are % yield loss (-).

Effect on seedling emergence

Yam seedling emergence was significantly affected by mound size and date of planting (Table 38). The time of emergence was longest for the large mound and shortest for the small mound. Similarly, the later the planting date the shorter was the time of emergence.

The effect of mound size on yam seedling emergence was related to soil moisture and temperature conditions. The quicker emergence from the small mound was believed to be associated with the shallow soil depth through which moisture from the soil below could readily be transferred by capillary diffusion to the developing seedling. With early planting in February emergence was slower due to dry conditions and high soil temperature, but with lat planting in April seedling emergence was quicker as a result of the cooler soil temperature and favourable soil moisture condition.

Table 38. Effect of mound size and planting date on the average time of yam seedling emergence (days/seedling),

Mound size	Planting date			Mean
	Feb. 26	March 29	April 30	
Large	12.6	9.4	8.8	10.3
Medium	5.9	6.1	4.6	5.5
Small	2.9	2.7	2.4	2.7
Mean	7.1	6.1	5.3	
LSD (%)		1.1		0.9
CV (%)	25.1			

(4) Economic implications of mound size reduction for the small farmer

In assessing the economic implications of the three mound sizes one finds that although the large size mound produces the beggest and most highly priced tubers it is the least income earner for the small farmer. By reducing the size of the large mound to accommodate more mounds within a given field and thereby increasing the crop density, a farmer could increase his production. Besides the higher total yield which could be derived, the choice of an appropriate mound size of a smaller nature could minimize yield loss due to nonstaking or late planting.

An appraisal of farmer's income and expenditure for the three mound sizes (Table 39) shows that a reduction in mound size resulted in higher income from yam sales. Although the medium and small size mounds derived the same income from sale the higher net return of the medium size mound indicates that it is a better alternative to the large mound in terms of overall economic gain.

Table 39. Estimated farmer income and expenditure from one hectare field of yam grown in three mound sizes.

Income and expenditure	Mound size and population per hectare		
	Large (2500)	Medium (5000)	Small (10000)
Cost of seed yams[1]	¢6000	¢12000	¢24000
Labour costs:			
Land clearing	3750	3750	3750
Mounding	4000	6000	8000
Planting[2]	-	-	-
Weeding (x3)	2000	2000	2000
Staking	-	-	-
Harvesting	300	450	650
Transportation to market	1500	2250	3000
Income from yam sale[3]	75,000	100,000	100,000
Net gain	¢75,450	m ¢73,550	¢58,650

[1]Cost of 1000 seed yams/2500 mounds at ¢600/100 seed yams. Each seed yam can be cut into 2-3 pieces for planting.

[2]Planting is normally done by the farmer and his family.

[3]Yam sale at ¢3000, ¢2000, ¢1000 per 100 tubers for the large, medium and small sizes, respectively.

b. Effect of tillage method and phosphate application on groundnut yield.

In groundnut production the method of seedbed preparation may vary from ridging or ploughing to little or no tillage after land clearing, depending on the farmer's cropping pattern. In Atebubu where the low, erratic rainfall pattern often creates droughty conditions that harden the already compacted fine texture alfisol, an appropriate tillage to loosen the soil is necessary for good groundnut growth and pod development.

During the major and minor cropping seasons of 1982 the performance of groundnut crop (var. Konkoma) was tested in seedbeds prepared by three methods, at three levels (0, 36 and 72 kg P_2O_5/ha) of phosphorus applied as single superphosphate. The results in Table 40 show that the no-tillage method with an accompanying crusting and hardening of the soil surface significantly reduced yields compared with ploughing and ridging which gave higher yields even without the application of phosphate fertilizer.

Table 40. Effect of tillage method and phosphate application on groundnut kernel yield (kg/ha).

Tillage method	P rate (kg P_2O_5/ha)			Mean
	0	36	17	
		Major season		
No-tillage	847	1195	1051	1031
Ploughing	1021	1257	1388	1222
Ridging	991	1313	1224	1176
Mean	953	1255	1221	
		Minor season		
No-tillage	371	469	508	449
Ploughing	516	644	664	608
Ridging	436	610	611	552
Mean	441	574	594	

Major season: CV (%) 13; LSD (5%) 129
Minor season; CV (%) 18; LSD (5%) 80.

5.4 Development of packages

Owing to the premature termination of the MIDAS project in its second year the research results obtained so far are inconclusive. Therefore, it is not practical to develop packages of recommendation which can be utilized by farmers, since these results require further testing. For example, the results of the yam mound size study demonstrate that the medium size mound is a better alternative to the large mound in terms of overall economic gain, but this has to be tested on farmers' fields to determine its suitability. Similarly, the preliminary varietal selections require further evaluation before the results can be utilized.

5.5 Farmers' reactions to new technologies

While conducting some trials on farmers' fields, we had good interaction with the farmers. Most farmers appreciated the need for fertilizer application to maize and upland rice but not for other crops. Many farmers showed interest in using herbicide for weed control as the manual weeding is labour intensive and the labour is scarce and expensive For similar reason, any innovation requiring more labour may not be well received by these farmers. Many farmers also understood the importance of row planting and maintaining optimum population for maize. But in the case of lowland rice the farmers did not appreciate line planting in close rows as it required a lot of labour; they preferred dibbling at random with a mean stand density of 80,000/ha. A few farmers showed interest in applying fertilizer in holes and covering it with soil.

6. DEVELOPMENT OF RESEARCH FARM AND TRAINING OF LOCAL STAFF

6.1 Development of the research farm and other infrastructural facilities at Atebubu and local staff training

A ten hectare research farm was marked out in the site designated for the MIDAS Project at a location which is about 5 km north-west of the Atebubu village. It was partly cleared by a shear balde and the stumps were mannually removed uring March-April 1981. The cleared land was prepared in a hurry and the first set of trials was laid out during April 1981. Owing to the very poor condition of the access road, this site was not accessible for many days during rainy seasons. The road was never built.

Toward the later part of 1981 it was decided to relocate the research farm in a site which is easily accessible all the year round. A new site adjacent to the Atebubu Training College on the Kumasi-Yeji road was acquired by February 1982. This site comprises an area of slightly more than 10 ha in four blocks. Some trials started in 1981 were continued at the old site while other trials were conducted at the new site.

A meteorological station established at the USAID residential site in Atebubu during May 1981. The fencing of the meteorological station was completed by August 1982. Construction of office, field laboratory, storage and watchmen sheds, and housing for the support staff never took-off. Fencing of the research farm never materialized. During 1982, one of the trailers at the residential site was converted into a temporary field laboratory to handle harvest produce and seeds. A rented room in the town was used for storing fertilizers, pesticides, tools, equipments, fuel, etc.

Throughout the project execution period, no Ghanaian counterpart staff was provided by the national organization (University of Science and Technology or Crops Research Institute, Kumasi). Thus, IITA scientists worked in isolation at Atebibu and were not able to train local talents to take care of the research work after their departure. Therefore, whatever progress the IITA scientists have made in the past two years and a half in establishing farming systems research capabilities in the Atebubu area would cease abruptly after their departure in late 1982.

There was virtually no progress in training of local staff. The two UST graduates, Messers Asiedu and Adu-Dapaah, selected for graduate training abroad are yet to be placed in a University. Similarly, no senior technical officer of the project was able to proceed to IITA for the six months in-service training in crop production technology due to Government restrictions on Ghanaians' travel abroad. Mr. Asiedu secured another scholarship for higher study and left for Australia in April 1982 after resigning from the MIDAS service.

Full compliment of the support staff (six STOs) was never achieved. Throughout the project execution period, only one or two STOs was on post. This also hampered the training schedule for the support staff.

7. PROBLEMS ENCOUNTERED DURING PROJECT IMPLEMENTATION

Several problems cropped up during the implementation period which very badly slowed down the progress of work. The important ones among them are briefly mentioned here.

7.1 Delay in the selection and development of the research farm at Atebubu

The first research site was identified at a location about 5 km north-west of the Atebubu village in February 1981, i.e. 8 months after the first IITA scientist arrived at Atebubu. It took another two months to clear part of the 10 hectare farm; land preparation was carried out hurriedly and the first set of trials was laid out in late April. Owing to the poor condition of the access road, this site was not accessible all the year round. The project vehicles broke-down several times on this road and caused serious hardship to the staff.

Because of the reported high cost of construction of the access road, attempts were made for about six months to find an alternative site which is easily accessible. In February 1982, a 10 ha farm adjacent to the Atebubu training college was acquired to service as the new research site. Most of the 1982 trials were conducted here while some trials started in 1981 were continued at the old site. The meteorological station was established in May 1981.

7.2 Lack of research infrastructure and inputs

Other problems encountered at the research site were absence of a field laboratory, storage and watchmen sheds, fencing for the experimental farm, tractor and other implements for land preparation (the project tractor arrived at Atebubu only in April 1982), and four-wheel drive vehicles to travel on the bad rural and farm roads. Most of the inputs needs for

research had to be brought in from IITA,Nigeria, with great difficulties to pass through national borders. Soil and plant samples could not be analyzed with in the country for want of chemical and laboratory wares and facilites.

7.3 Poor linkage with national institutes, absence of counterpart staff and inadequate support staff

The University of Science and Technology (UST) Kumasi, was to act as the national counterpart institute for the MIDAS research component. Because their participation was poor and disappointing, their role was shifted to the Crops Research Institute (CRI), Kumasi, toward the end of 1981. By this time the USAID funding support for the MIDAS components including research was temporarily curtailed pending the improvement in the capability of GOG to fulfil their counterpart funding obligations. This dampened the interest of CRI in collaborating with MIDAS Project.

Both the institutions could not provide qualified counterpart staff to work with IITA scientists at Atebubu. Therefore, whatever progress the outside experts have made during 1980-82 in establishing farming system research capabilities in the Atebubu area would soon vanish in the absence of trained local scientists to take over their work after their departure.

Throughout the project execution period, full compliment of the support staff (6 senior technical officers and other low level staff) was never achieved; only one or two STOs was present at any time during this period. Lack of support staff hindered progress of research activities, particularly the conduct of on-farm trials. This situation also prevented the deputation of staff for in-service training at IITA. Absence of secretarial help for most part of the period impeded the work at the office.

7.4 Poor service conditions of local staff

The technical staff and labourers working in the MIDAS research program were not clear about their service conditions. They had problems in obtaining their share of rationed commodities supplied through various organizations. Regularisation of their status either as civil servants or as research staff was not done until the termination of the project. The technical officers were not provided with motor bikes and so they could not do their work efficiently. Housing was a big problem for them. All these factors dampened their enthusiasm and badly afftected their morale. A few of them resigned after sometime out of frustration.

7.5 Short time span and uncertainty in project continuation

Three years are too short for the implementation of a project on farming systems. Moreover, all the facilities, staff and other supports were not in place even two years after the initiation of the project. As such progress was very hard to achieve.

The uncertainty in the continuation of the project, felt around the later part of 1981, hindered progress very badly. Long-term soil management and crop rotation trials could not be started. The uncertainty increased the anxiety and frustration of the local staff and adversely affected their morale.

7.6 No progress in the training and development of local staff

There was virtually no progress in the graduate and in-service training of local staff due to delay in recruitment, problems in securing admission in outside institutions, Government's foreign travel restriction, etc. This badly affected the success of the project.

8. RECOMENDATIONS FOR USE OF 1980-82 RESULTS AND SUGGESTIONS FOR FUTURE FSR STUDIES IN GHANA

8.1 Recommended use of the data obtained from 1980-82 studies

The studies conducted during 1980-82 show that the Atebubu area has the following constraints limiting food crop production:

i. Climate:

There is a highly irregular sequence of dry and wet years, with no discernible cycle. Variability in the time of start, time of cessation, monthly and daily distribution within the season and shifts in the peak rainfall periods is very high. The commonly occuring wet and dry spells during the rainy season cause untold problems. Wet spells encourage erosion leaching and waterlogging in fields while shifts in peak rainfall period cause problems in scheduling farm operation, particularly land preparation, planting, harvesting and post-harvest operation. On the other hand, short midseason droughts cause wilting, especially of shallow rooted crops and on shallow soils.

Suggested solution:

(a) Planting of crops, particularly cereals, should be staggered as much as possible over a long planting season. This is very true for maize; some farmers planted only one maize crop between the two rainy seasons and got good yields. This is better than trying to raise two uncertain crops in a year. (b) It is also necessary to identify short season and drought resistant varieties of maize and rice suitable for this area. Alternatively cultivation of cowpea should be encouraged in poor rainfall zones.

ii. Soil productivity

Parent material and clay mineralogy are among the key factors controlling soil productivity. According to Juo (1981) the productivity of soils decreases in the following order depending on the parent material and clay mineralogy:

Parent material vs. soil productivity

1) Soils derived from basic volcanic ash
2) Soils derived from basic rocks (e.g. limestone, basalt, amphibolite)
3) Soils derived from intermediate rocks (e.g. granites, gneisses)
4) Soils derived from acidic rocks (e.g. sandstone, quartzite).

Clay mineralogy (or ECEC) vs. soil productivity

1) Montmorillonitic soils
2) Allophanic soils
3) Vermiculitic or illitic soils
4) Oxidic soils
5) Kaolinitic soils
6) Silicious soils

Soils in the Atebubu area have developed from the Voltaian Sediments (fine-grained and quartz sandstone, mudstone, shale, conglomerate and pebbles) which are acidic in nature; therefore, productivity of these soils is low. Since the effective cation exchange capacity is low, the clay mineralogy is assumed to be mostly kaolinitic or silicious, again pointing out low productivity. Upland soils derived from mudstone and shale are high in silt content and poor in soil-water-plant relationship, e.g. Kumayili, Nyankpala and Kpelesawgu series. Soils derived from sandstones are slightly better in soil-water-plant relationship, e.g Ejura, Amantin series. In general upland soils suffer from low inherent fertility, poor moisture

relations, imperfect subsoil drainage, erosion hazard on slopes greater than 5% and shallow depth and high gravel content of some soils. Hydromorphic soils are fairly high in fertility, but suffer from poor drainage, flood hazard, and poor accessibility as well as prevalence of fly- and river-borne diseases.

Suggested solution:

(a) Management of these soils calls for the maintenance of soil organic matter through fertilizer use, addition of organic waste and manures, etc. High-energy input systems require imported inputs whereas low-input systems can be practiced with the locally available resources. (b) Agroforestry is highly recommended as an alternative to shifting cultivation to manage soil fertility efficiently. This system also provides fuel wood, stakes and fodder in addition to green manure. (c) Rotation of legumes with cereals will reduce the fertilizer N requirement of the system and improve the protein content in the diet. Groundnut and cowpea are important legumes in this region and their cultivation in a fixed rotation should be encouraged. There is no need for Rhizobium inoculation of groundnut. (d) Planted fallows is another possibility to hasten soil regeneration after cropping. (e) The present exploitative land tenure system which encourages land misuse should be changed to promote soil conservation. (f) Intensive exploitation of valley bottom soils should be promoted by the provision of drainage and water control measures, eradication of diseases and improvement of accessibility.

iii. Crop productivity

Besides insect pest and disease problems, the scarcity of improved varieties, low crop density, lack of appropriate methods of seedbed preparation and weed problems are some of the major factors contributing to low crop yields.

a. Variety testing:

By testing for adaptability among improved varieties, those crop varieties which are found suitable for the Atebubu area can be selected.

Recommendation:

Since the 1981 test results are only preliminary, further evaluation of the selected varieties particularly at the farm level is necessary so as to involve the farmer in selecting the varieties which meet his requirement of yield, maturity, and pest and disease resistance. The varieties selected for further testing are:

Maize:

IITA, CRI and the following CIMMYT varieties; Guanacaste 7729, Los Boanos 7622, La Maquina 7843, Poza Rica 7822, Across 7728 and Across 7643.

Rice:

ITA-121, ITA-123, ITA-212, TOX 711 and ITA-116.

Sorghum:

The fact that most of the varieties tested suffered head mould fungus attack suggests that sorghum varieties which have open or less compact heads with high yield potential should be introduced and evaluated.

Groundnut:

MK 374, Florispan Runner, Konkoma and shitochi

Cowpea:

Vita 5, Vita 8, Vita 4 and TVx 1845-1e.

Since less emphasis on variety testing was recommended by MIDAS Adhoc Committee, it is important that the extension service should make available to all farmers the improved crop varieties that have been developed and tested by CRI.

b. Yam mound size and population density:

In a study of yam mound size in relation to mound population density, staking and time of planting, it was observed that the large mound size with a population of 2,500 mounds per hectare gave lower yield and economic return than medium size mound with a population of 5,000 mounds per hectare. The medium size mound also reduced yield losses associated with non-staking and late planting. Water penetration in large mounds was observed to be poor too.

Recommendation:

(1) The above finding should be further tested and validated at the farm level before farmers are advised to increase yam mound density to 5,000/ha. (2) To reduce labour problem in making yam mounds, studies on mechanical (tractor) ridging and planting yam on ridges insteas of mounds should be undertaken.

c. Tillage for goundnut:

Some kind of land preparation, viz. ploughing or ridging is necessary to obtain good groundnut yield. A no-tillage method reduced yield significantly.

Suggested use:

This finding discourages zero tillage on these soils for groundnut cultivation.

d. Weed problems:

Weeds constitute a major problem in all the cropping systems. Mannual weeding is labour intensive and not very effective due to poor execution. Local rice farmers indicated that they need herbicides to control weeds before they can increase rice yields with fertilizer.

Recommendation

Studies on herbicide weed control along with improved cropping system to shade out weeds and identification of crops or crop varieties that effectively suppress weed growth should be undertaken.

8.2 Formulation of model FSR projects for the transition zone of Ghana and time frame to execute them

A. Study of the alley cropping system as an alternative to shifting cultivation

Three pahses are involved in developing alley cropping packages for farmers. They are as follows:

Phase 1: Replicated field trials - 4 to 5 years

A limited number of well replicated field trials will be laid out on selected sites representing different soil climatic zones to collect agronomic data on the proposed system. The activities to be undertaken are:

a) Establishment of the leucaena and/or glyricidia alleys - two years.

b) Study the rate of establishment, growth and biomass production and factors affecting them - two to three years.

c) Management trials with associated food crops such as yam, maize, cowpea, etc. This can concurrently proceed with (b) above.

Phase 2: Verification/demonstration of alley cropping - 4 years

Here large production plots (0.2 to 0.5 hectare) will be established on selected farmer's fields to compare the agronomic and economic efficiency of alley cropping with the present technology and their ability to adopt the new system will be closely monitored.

Phase 3: Extension of the developed alley cropping pakcage to farmers.

B. Development of Cereal-legume cropping systems

Phase 1: Replicated field trials - 5 years

Well replicated small plot field trials will be conducted at selected centres on:

Rotations: Maize/groundnut or cowpea, maize/sorghum, maize/upland rice.

Intercropping: Maize/groundnut mixture, maize monocrop, groundnut monocrop, maize/groundnut relay.

Legume green manure: Centrosema/mazie, Sesbania/maize.

Strip cropping: Maize/groundnut strips, maize/cowpea strips, maize monocrop, groundnut monocrop, cowpea monocrop.

Phase 2: Verification/demonstration of cereal/legume cropping system - 3 to 4 years.

Promomising cereal/legume cropping system will be tested on farmers' fields in large production plots to monitor their economic feasibility and social acceptability.

Phase 3: Extension to farmers of successful packages.

8.3 Staff requirement for FSR studies

Two or three sites can be selected for initiation of farming systems research; the possible sites in the transition zone will be Atebubu, Mampong/Nkoranza and Wenchi. A technology testing team consisting of one or two agronomists and four technical officers with adequate number of workers should be located in each site. An agricultural economist or social scientist from the Crops Research Institute (CRI), Kumasi, can assist the field teams periodically on diagnostic and monitoring surveys. One agronomist, agronomist/soil scientist located at CRI, Kumasi, should coordinate and guide the field teams on the conduct of farming systems research, particularly the on-farm experimentation. He should also arrange for the training of field staff in FSR. Specialists working on component technologies

and located at CRI will help the FSR coordinator to design suitable technologies for testing on the field. Secretarial help should be provided at the central and field offices.

8.4 Resource requirement

The following minimum facilities should be provided at each location:

Research farm	-	1
Field laboratory	-	1
Office space	-	4 rooms
Store	-	1
Watchmen shed	-	2
Housing	-	2 senior staff
"	-	10 junior staff
Tractor	-	1 (40 horsepower)
Pick-up van	-	2
Motor bike	-	4
Bicycles		10
Implements, tools, supplies and consumables		

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10. APPENDIX

10.1 Project reports and publication

i. Reports

a) Quarterly progress report of the MIDAS Research Program submitted to the MIDAS Project Executive Committee through the Project Manager for the periods from July 1980 to June 1982. Total quarterly reports are eight.

b) Semi-annual progress reports to USAID/Ghana. Total semi-annual reports submitted are four covering the period from July 1981 to June 1982.

c) Annual Progress Reports of the MIDAS Small Farms Systems Research Program - 1981

d) Terminal Report for the Research Program.

ii. Publications from the project work

a) Balasubramanian, V., J.O. Braide and E.A. Atayi. 1982. An appraisal of the present farming systems of the ATebubu District of Ghana. Int. Inst. Trop. Agr., Ibadan. Nigeria.

b) Balasubramanian, V. 1982. Maize research by MIDAS. Paper presented at the Second National Maize Workshop held at Kwadaso Agricultural College, Kumasi, Ghana, Feb. 23-25, 1982

c) Balasubramanian, V. 1983. Alley cropping: can it be an alternative to chemical fertilizers in Ghana? An invited paper presented at the third National Maize Workshop held at the Kwadaso Agricultural College, Kumasi, Ghana, Feb. 1-3, 1983.

10.2 List of National Institutions which cooperated with MIDAS Research Project.

1.	University of Science and Technology (UST), Kumasi.	Supply of trained manpower for the Project.
2.	University of Ghana, Legon	
3.	Dept. of Agric. Engineering, UST, Kumasi.	Cooperates in testing small farmer implements such as maize sheller, planter, storage bin, etc.
4.	Soil Research Institute, Kumasi.	Conducted detailed soil survey of the research site; helps in soil classification and management problems.
5.	Crop Research Institute, Kumasi.	Supply of improved seeds.
6.	Grains and Legumes Development Board (GLDB), Kumasi	Collaboration for maize research.
7.	Agric. Extension staff, Atebubu District.	Helps in running on-farm trials.

10.3 List of abreviations used in the text

B	-	Boron
BS	-	Base saturation
C	-	Carbon
Ca	-	Calcium
CIDA	-	Canadian International Development Agency
CIMMYT	-	International Centre for Wheat and Maize
CRI	-	Crops Research Institute
cv.	-	Cultivar
C.V	-	Coefficient of Variability
ECEC	-	Effective Cation Exchange Capacity
FAO	-	Food and Agricultural Organization
F.C	-	Field capacity
FSR	-	Farming systems Research
GLDB	-	Grains and Legumes Development Board
ha	-	Hectare
IITA	-	International Institute of Tropical Agriculture
K	-	Potassium; K_2O - Potassium expressed in oxide form
KCI	-	Potassium chloride
kg	-	Kilogram
km	-	Kilometre
LSD	-	Least Significant Difference
me	-	Millioquivalent
μ	-	Micro
Mg	-	Magnesium
Mo	-	Molybdenum

MOA	-	Ministry of Agriculture
Mn	-	Manganese
N	-	Nitrogen
Na	-	Sodium
NCSU	-	North Carolina State University
NifTAL	-	Nitrogen Fixation in Tropical Agricultural Legumes
P	-	Sulphur
s.d.	-	Standard deviation from the mean
SE	-	Standard error of the mean
SFCC	-	Soil Fertility Capability Classification
SRI	-	Soils Research Institute
STO	-	Senior Technical Officer
t	-	Metric tonnes
TO	-	Technical Officer
UN	-	United Nations
USAID	-	United States Agency for International Development
USDA	-	United States Department of Agriculture
UST	-	University of Science and Technology
Var.	-	Variety
WAP	-	Weeks After Planting
W.P.	-	Wilting point
Zn	-	Zinc