THE CSIR - SOIL RESEARCH INSTITUTE (GHANA)/KINKI UNIVERSITY (JAPAN) JOINT STUDY PROJECT.

OUTLINE OF YEAR 2005 ACTIVITIES AND THE WAY FORWARD

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CONTENTS

GENERAL INTRODUCTION

The “sawah” project has its overall objective of bringing about food security in Ghana through increased and sustained production of rice. Specifically, the “sawah” system intends to achieve this noble objective through (i) increased and sustainable rice production, (ii) restoration of degraded environment through the conservation of soil, water and forest, (iii) increase in rural income and improvement in rural livelihood, and (iv) the creation of beautiful and cultural rural society and landscape. In line with the above, a number of activities were either continued or initiated and executed during the year 2005 all geared towards realizing the key goal of the project. Some of these projects/activities include:

1. Preparation of a manual for Inland Valleys “Sawah” Development and Rice cultivation:

2. Hydrological flow characteristics of various rivers in Benchmark sites

3. Lowland characterization of Benchmark sites for various potential "sawah" development

4. Soil fertility and water management under “sawah” systems

5.Evaluation of sustainable rice-based cropping systems in the Inland valleys under “sawah”

Development: Training of farmers and MoFA staff on the principles of the “sawah” technology during the year.

The way forward has been added indicating what needs to be further done in order for the project to achieve its goal of providing food security through increased rice production.

1. MANUAL FOR INLAND VALLEYS “SAWAH” DEVELOPMENT AND RICE CULTIVATION:

Buri M.M, Issaka R. N., Opong J., Seneyah S. K, Annan E. A, Ofori J., Wakatsuki T.

The first draft of this manual under the main topics listed below has been prepared and is currently under review.

“Sawah” Development and Management

Irrigation Development and Management

Agronomy Practices

Post Harvest

Marketing and Financial Management

Way forward:

Requires updating/grading of information on the submitted draft. Not much information on certain areas was provided in the first draft. Work to continue to fine tune the information to bring it up too the standard of complete manual

2. HYDROLOGICAL FLOW CHARACTERISTICS OF VARIOUS RIVERS IN BENCHMARK SITES:

Oppong James, Buri M. M. and Wakatsuki T

Introduction.

"Sawah" technology, introduced to Ghana through the support of the Japanese government, has revolutionarized rice production in some parts of the country. Ghana's aim of achieving self-sufficiency in rice production could be met in the short term if the rain-fed, low-input rice production is improved upon by the adoption of "sawah" technology. "Sawah" is a form of level basin irrigation where water flows by gravity into a level field enclosed by earth bunds. The system of bunds and channels retains, distributes and discharges water according to the crop water requirement It impounds and stores rain water, flood water and/or spring water to feed the crop. The bunds (levees) besides serving as dams to retain ponded water also protect the rice from flood damages and also serve as pathways. The "sawah" is thus a self-irrigating system for rice cultivation.

A JICA funded 'Integrated watershed management of inland valleys in Ghana and West Africa project' with special emphasis on "sawah" development in the Ahafo Ano district specifically in the Mankran watershed has whipped up interest in rice cultivation of small scale farmers in the area and there has been an overwhelming request by other farmers to introduce the technology to them. However, "sawah" thrives on availability of water. This study was therefore undertaken to assess the hydrological characteristic, in terms of water quality and quantity available in the Mankran catchment, for its potential for "sawah" expansion. It is meant specifically to determine the irrigable area by assessing the main-d'eau of the major rivers of the Mankran catchment, which traverses the whole of the Ahafo Ano District.

It is usually less expensive to site “sawah” in low-lying river valleys for two major reasons; (i) to eliminate or minimize lift energy and cost of water delivery to the field. Water flows into a “sawah” mainly by gravity so as to minimize its delivery by pumps., (ii) to minimize earth movement due to cut and fill and levelling of field to minimize investment cost of the resource poor farmer.

Specific objectives of the study are therefore to measure; (i) the discharge of the main rivers and their tributaries to assess their main-d’eau and their possible irrigable area, (ii) the seasonal flood regimes of the major rivers and their tributaries (iii) the quality of irrigable water, (iv) the cycle of changes in the water volume of the rivers. And to advice farmers on, and (v) the best time of planting their rice.

Materials and Methods**:**

Study Area: The Mankran Watershed covers about 700sq km. The main river is the Mankrankese with its tributaries. The major tributaries on which the study was conducted were Biem, Dwinyan, Mankrankuma and Asikesu. Two rivers Punpunya and Aponapono (Rice Valley), which are tributaries of Dwinyan were included in the study due to the concentration of rain fed rice farms around them. Figure1 shows the map of the study area and the experimental sites.

The study was done during the 2005 minor season from August to December. Data was collected on the rainfall of the area, discharge of the rivers, and predominant textural classes of soils in the valley, their saturated hydraulic conductivities and gravimetric water content at saturation. Rainfall data was taken from a manual rain gauge mounted at a central point in a forest reserve. Data on hydraulic conductivities (disc infiltrometer method) of some soils and their gravimetric moisture content were also taken

Measurement of discharge: The discharge of the experimental rivers (L/s/m) was measured by the surface velocity method. A float placed between two poles 2m apart in the direction of the flow of the rivers was timed. The distance divided by the time gave surface velocity (Vs), which was multiplied by 0.8 as a rule of thumb to give V. The area (A) was found by measuring the depths at three points and the average depth multiplied by the width of the cross-section at which the depth was taken. The discharge Q = AV. The discharges of the major rivers were measured fortnightly for 12 sites on the major rivers and their tributaries.

Results:

Rainfall: Precipitation is the main source of water that recharges the rivers. During the period of study a total of about 530mm of rainfall was recorded with more than 72% falling in September and October.

Table 1: Fortnightly Cumulative Rainfall for the study Period.

	Month (2005)				
Period	August	September	October	November	December
1st half	9.7	10.5	106.7	57.6	10.0
2nd half	27.9	188.5	75.3	42.0	0
Total	37.6	199.0	182.0	99.6	10

Soil Physical properties: Soils in the valley are predominantly silty loam, sandy loam and some cracking clays that are mostly found at the lower Mankran valley. Their hydraulic conductivities are; Sandy loam - 8.44 x 10^{-4} cm/s, Silty loam - 5.4 x 10^{-4} cm/s, Clays loam - 0.8 x 10^{-4} cm/s. Percentage gravimetric moisture content of the saturated soils hardly exceeded 23 %.

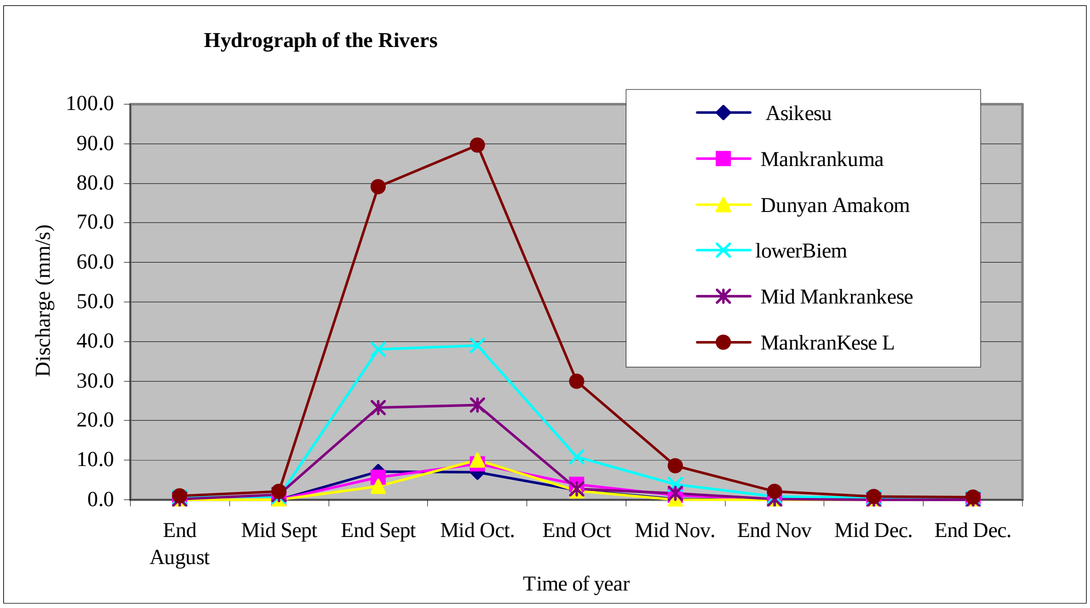
Discharge of the rivers: The hydrograph (Figure1 and Table 2) shows the changes of flow volume during the study period

With a discharge of 24.9 m^3/s the Lower Mankran can irrigate more than 800 ha if used as the main-d'eau. The peak flood provides more than 100 times the water in mid August when the water level was lowest for the study period.

Table2: Discharge in L/s/m ($X10^3$) of the major rivers.

River	Period								
	End Aug	Mid Sept	End Sept	Mid Oct.	End Oct	Mid Nov.	End Nov	Mid Dec.	End Dec.
Asikesu	0.0	0.0	7.2	7.0	2.4	0.1	0.0	0.0	0.0
Mankrankuma	0.0	0.0	5.7	9.0	4.0	1.1	0.1	0.0	0.0
Dunyan	0.0	0.0	3.5	10.0	2.2	0.0	0.0	0.0	0.0
Biem	0.7	0.7	38.0	39.0	10.8	4.0	0.7	0.5	0.4
Mid Mankrankese	0.1	1.3	23.4	24.0	2.7	1.6	0.1	0.0	0.0
Lower ManKranKese	0.9	2.1	79.2	89.6	29.9	8.6	2.0	0.9	0.7

Fig. 1: The hydrograph for the rivers.



Water Quality

Analysis of water samples (Table 3) for pH, total N, Phosphorus and the cations indicated that the water from the rivers are all neutral with a pH range of 6.8 to 7.2. Almost all rivers were quite rich in the basic cations (K, Ca, Mg, Na). The higher levels of these cations will greatly serve to relive farmers of any supplementary additions particularly Ca and Mg. However, the higher observed levels of Na (probably coming from rubbish dumps on the river banks) could pose future problems due to the negative effect of excess Na on rice growth and yields.

Table 3: Water Quality of selected rivers

	Parameter							
River	pH	TN mg/l	P mg/g	K mg/g	Na mg/kg	Ca mg/l	Mg mg/l	Fe mg/kg
Asikesu	7.2	0.21	0.10	19.9	40.0	51.3	30.1	-
Mankrankuma	7.1	0.41	0.07	8.2	9.9	22.4	16.0	-
Dunyan	6.8	0.44	0.27	7.10	10.8	16.2	12.6	-
Biem	7.1	0.52	0.34	3.5	7.8	9.8	6.8	10.0
Mid Mankrankese	7.0	0.21	0.46	4.5	8.7	10.8	6.6	-
Lower MankranKese	7.1	0.44	0.75	5.9	8.2	18.8	10.8	15.0

Conclusion and Recommendations

It is recommended that the study be repeated for three more seasons to subject the data collected to statistical analysis using the different seasons as replicates for different sites and to also get a rough idea about the recurrence of peak flood events for designing the type of weir

3. LOWLAND CHARACTERIZATION OF BENCHMARK SITES FOR VARIOUS POTENTIAL "SAWAH" DEVELOPMENT.

Characterization of selected inland valleys sites for “Sawah” Development

Seneyah J. K.. Buri M. M., Gaise K., Asubonteng K. O., Wakatsuki T

Introduction

The landscape generally varies in characteristics such as soil, topography, drainage, land cover etc. Such variations also exist in inland valleys. Various sites in selected valleys were studied and on the basis of their characteristics determine their suitability or potential for the development of various types of ‘sawah’.

The “sawah” system primarily involves the creation of an environment that efficiently controls water for rice production by leveling, puddling and bunding with inlets and outlets connecting irrigation and drainage systems (Wakatsuki T., 1996).

The “sawah” system is sustained by conditions such as

- The supply of water either by rain or irrigation with the water drawn from a pond or a reservoir
- The means by which the water is delivered to the fields e.g. by pump, canal, pipes
- Drainage facilities / structures to remove excess water

Generally in West Africa, the land is used in a continuum of the whole topo-sequence with the cultivation of crops from the upland to the inland valley (WARDA / ADRAO, 1995). The farming system in the study area therefore involves the cultivation of rice as a major crop in the inland valleys and oil palm, which is now gaining popularity. On the hydromorphic fringes and upland, cocoa, oil palm, citrus and food crops such as maize, cassava, plantain etc are grown.

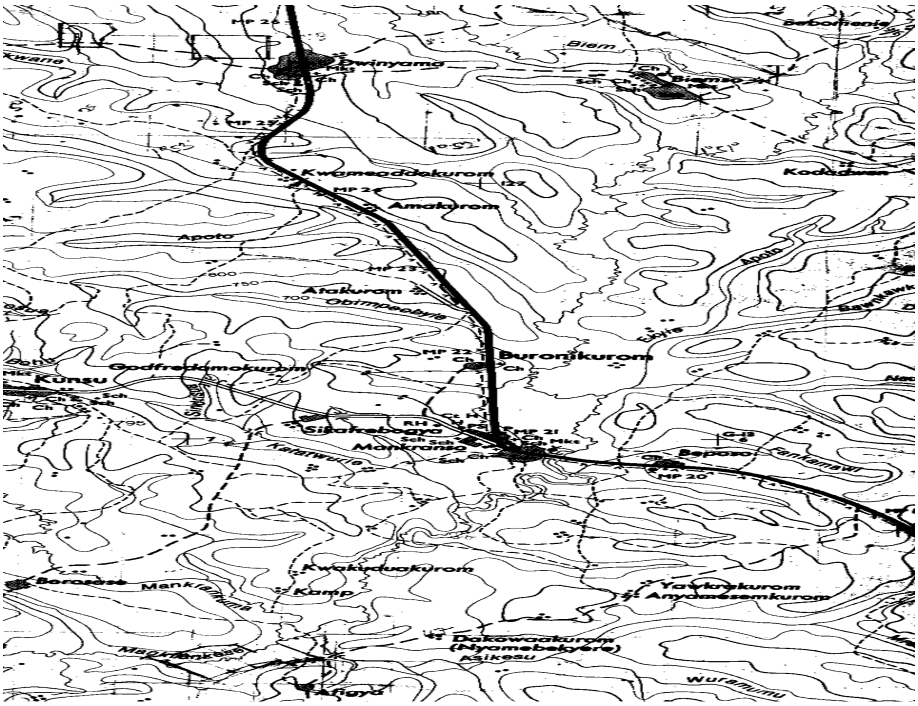
Objectives

The objective of the characterization process were set out as follows:

- To identify and describe the morphological characteristics of the soils in the selected valley sites
- To determine the fertility and other chemical properties of the soils
- To determine the moisture characteristics of the soils
- To assess each site for the appropriate sawah type

Methodology:

Secondary data collection on climate, vegetation and soil was gathered from available reports on the sites (Adu, 1992). Topographical map at a scale of 1:50,000 is used as a base map.



A reconnaissance visit was made to several inland valley sites within the Mankran, Piakwane, Dwinyai and Biem valleys, which assisted in the selection and planning of the main fieldwork for data collection.

The field data was collected along grids laid at different measurements on the basis of width of valley and the lengthwise extent to allow for the capture of significant landforms.

At Afigya (Ahwiaa), traverses were laid at 200 metres apart and examination and sampling carried out at 100 metres interval along the traverses (200 x 100m grid). At Adugyama, in the Dwinyan valley, the grid was 100 x100 metres, while the Gold valley was 100 x 50 metres. At Biemso No. 1, the narrow portion of the valley (i.e. from the dyke towards the bridge) was studied at 100 x 50 metres grid while the wider portion from the direction of flow was investigated at 100 x 100 metres grid.

At each point of examination, mini-pits were dug to at least 60cm depth and the soil identified and described. The parameters described were, texture by hand manipulation, drainage, coarse fragment content and effective depth.

Soil samples were taken at each mini-pit at 0 –30 cm and 30 – 60 cm depths for fertility evaluation and at 0 – 15 and 15 – 30 cm for determination of physical properties such as bulk density, moisture retention capacity and particle size analyses.

Profile pits will be dug at Biemso No. 1 on Kakum and Temang series, described and sampled for laboratory analyses

2.0 ENVIRONMENTAL CONDITIONS OF THE AREA

2.1 Climate

The study sites are located in the semi-deciduous agro-ecological zone. The zone is characterized by relatively high rainfall (about 4500mm per annum) with a bimodal pattern. The major season rains occur between March and mid-July with a peak in May/June. There is a short dry spell from mid-July to mid-August. The minor rainy season starts from mid-August to about the end of October with a peak in September. A long dry period is experienced from November to February with possibilities of occasional rains.

Mankranso – Adugyama – Biemso area, where the studies were carried out are located in between Kumasi and Bechem. Climatic data on Kumasi and Bechem are therefore used to represent the study area. The rains appear to be nearly well distributed throughout the year, with the amounts considered adequate for crop production occurring in the two peaks earlier mentioned – April to July and September to October (figs a &b). The mean annual rainfall for Kumasi and Bechem are 1402 and 1172 respectively. About 46 – 48% of the total annual rainfall occurs in April – July, which is the major rainy season while the minor season from September to November has 28 – 30% of the annual rains.

Temperatures are normally high throughout the year with very little variations. The mean monthly temperatures range from 25^{o}C in July/August to 29^{o}C in March/April

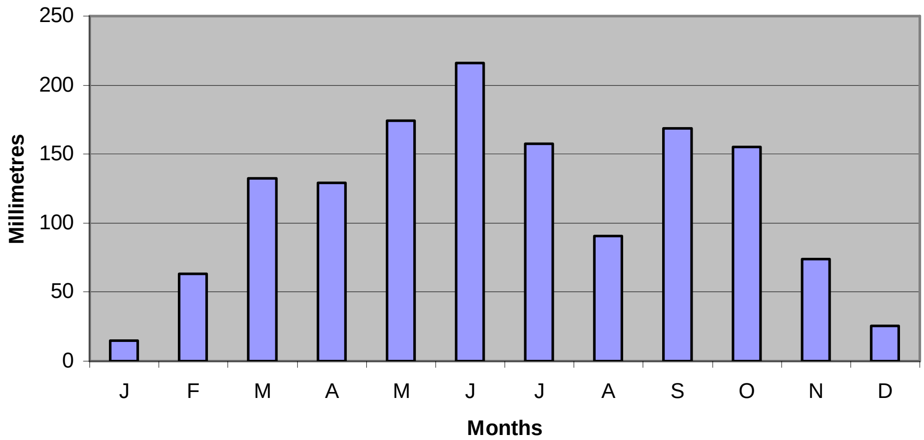


Fig. 2 Kumasi: Mean monthly rainfall

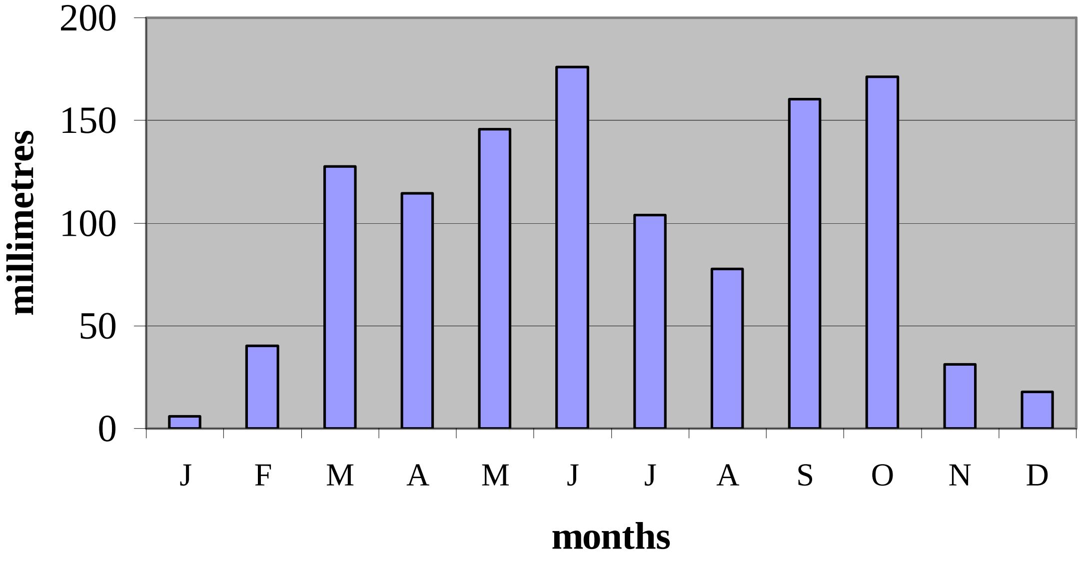


Fig. 3 Bechem: mean monthly rainfall:

2.2 Geology

The study area consists of rocks of the Lower Birimian formation comprising phyllites, greywackes, schists and gneiss. They were laid down early in geological times and consist mainly of clay deposits, subsequently hardened and altered by heat and pressure (Adu, 1992). The alluvial soils are derived from localized materials of the Lower Birimian formation.

Veins and stringers of quartz injected into the phyllite break up during weathering to give stones and gravel. Because of the uneven distribution of these veins the amount of quartz stones and gravel in the soil varies considerably and may be locally abundant. Such numerous stones and gravel seriously reduce the capacity of the subsoil to store water and plant nutrients.

2.3 Vegetation and Land-use

The natural vegetation of the study sites falls within the semi-deciduous forest zone of Ghana (Taylor, 1952). Except for reserved areas, the original vegetation, which normally is a continuous canopy of tall and medium height trees is degraded and the present cover consists mainly of farmlands, thickets over fallow lands and few patches of secondary forest.

Thickets also occur linearly along the stream courses with bamboo and ogyama being common. The lowlands are characterized by grass, *Panicum maximum* and elephant grass. Raised terraces or ant-hills, which are common within the valleys commonly have tree shrubs growing on them due to the good soil drainage.

Agriculture is the dominant landuse in the area. The lowlands are commonly cultivated to rice, oil palm and vegetables. The uplands are also grown to food crops like maize, cassava and plantain and tree cash crops like cocoa, citrus and oil palm.

2.4 Soils

The soils of the study sites are developed from the Lower Birimian rocks. The soils fall under the Akumadan – Bekwai / Oda Complex association at Adugyama and Biemso sites and Bekwai – Zongo / Oda Complex at Awhiaa (Adu, 1992). In a topo-sequence, the Akumadan – Bekwai / Oda Complex consists of very deep, red, well drained *(Akumadan series)* and brown, moderately well drained *(Afrancho series)* sandy loam drift soils, which occupies almost flat hilltops; sheet ironpan *(Wenchi series)* and brown dominantly concretionary drift soils overlying ironpan *(Domenase series)* occur as collars around the edges of the Akumadan soils. These are followed downslope on upper and middle slopes by *Bekwai* and *Nzima series* respectively, which consist of red, well drained and brown moderately well drained silty clay loams, with moderate amounts of quartz gravel and ironstone concretions in their subsoil. The lower slope is occupied by imperfectly drained gravel–free yellow brown silty clay loams, *Kokofu series,* which are developed from colluvium from upslope. The valley bottom is occupied by grey, poorly drained alluvial loamy sands, *Temang series* and clays *Oda series.* Most of the major streams are flanked by low, almost flat (0 – 2%) alluvial terrace consisting of deep, yellowish brown, moderately well to imperfectly drained silty clay loams, *Kakum series.* The Bekwai – Zongo / Oda complex association also consists of Bekwai, Nzima, Kokofu, Temang, Oda and Kakum series but in addition, it has a large tract of seepage ironpan soils *(Zongo series).* Zongo soils consist of sandy loam topsoil overlying yellow brown, imperfectly drained, clay loams containing ironstone concretions and ironpan boulders in the subsoil.

In some places, Nzima soils are characterized by a high content of stones and gravel resulting from the break up during weathering of veins and stringers of quartz injected into the phyllite. This soil is *Mim series.*

3.0 RESULTS

3.1 Description of the soils

The soils found at the sites are presented in table x1.

Table 1. Soils at the characterized sites

Sites	S O I L S (series name)		
	Upland	Fringes	Valley
Biemso No.1	Afrancho, Mim	Kokofu	Temang, Kakum
Afigya (Ahwiaa)	Mim, Nzima, Zongo	Kokofu	Temang
Dwinyan	Bekwai, Nzima	Kokofu	Temang, Kakum
Gold valley	Bekwai, Zongo	-	Temang

Afrancho series

Afrancho series occurs on middle to upper slopes. It may sometimes extend to the summit. The soil is deep, well to moderately well drained, non-gravelly and non-concretionary. The topsoil is dark reddish brown, friable silt loam. The underlying subsoil is strong brown to yellowish red silty clay loam. It has a moderate medium subangular blocky structure.

Bekwai Series

Bekwai series occur on summits and upper slopes on undulating topography. *Bekwai series* is a deep in-situ developed well-drained, red, silty clay loam soil containing many quartz gravels.

The profile consists of 0 - 9cm topsoil of Dark reddish brown, sandy or silty loam. It is friable with fine and medium granular structure. This overlies over 150cm deep subsoil of red silty clay loam with a moderate medium subangular blocky structure. The subsoil contains common to many quartz gravels and iron concretions.

Nzima Series

Nzima series usually occupies the upper and middle slopes and sometimes extends to the summits of undulating topography. The soil has a morphological characteristic similar to *Bekwai series* except for colour. It is deep, well to moderately well drained. The topsoil consists of 0 -11cm dark brown silty loam. It is friable with weak fine and medium granular structure. The subsoil consists of yellowish brown to strong brown silty clay loam, which contains many quartz gravels and ironstone concretions. It is firm and has a moderate medium sub-angular blocky structure.

Mim series

Mim series is a moderately well to well drained soil found on middle slopes of 5 – 8%. The topsoil is dark reddish brown sandy loam. This overlies many to abundant (40 – 80%) quartz gravel and stones in a reddish brown clay loam soil. This soil seem similar to Nzima series but differs by the higher gravel and stone content in the subsoil. Its effective depth is determined by the amount of quartz gravel and stones, where it becomes so abundant that there is only little soil material, which varies between 30 and 60cm.

Zongo series

Zongo series is a moderately well to imperfectly drained soil, found on middle to lower slopes. The topsoil is dark grey sandy loam. The underlying subsoil is pale brown sandy clay loam containing ironstone gravel from 40cm, which increases with depth from many (15-40%) to abundant (40-80%).

Kokofu series

Kokofu series, is found below Nzima series and occupies lower slope sites with slope gradients of 1 – 3%. It is developed from colluvial material from upslope. The soil is deep, non-gravelly and moderately well or imperfectly drained. The topsoil consists of dark brown friable silt loam. The underlying subsoil consists of yellowish brown silty clay loam, faintly mottled yellow.

Temang series

This soil is developed from alluvial material and occupies the valley bottoms of 0 – 1% slope and depressions that are subjected to water-logging during the rainy season. The soil is deep and poorly drained. The topsoil consists of brown, faintly mottled dark yellowish brown friable loam. The underlying subsoil is pale brown to light brownish gray friable sandy loam with dark yellowish brown mottles.

Kakum Series

Kakum soils are very deep (>150cm), imperfectly to moderately well drained, occurring on the slightly raised old alluvial flats along the banks of the major streams. The profile consists of dark brown, weak granular friable sandy loam at the topsoil. The subsoil is yellowish brown and faintly mottled strong brown friable clay loam and a structure that is weak to moderate fine and medium sub-angular blocky. Below 100cm, the mottles become prominently reddish yellow.

3.2 The study sites and their suitability for 'sawah' development

Afigya (Ahwiaa):

Dry lowland suitable for oil palm, cacao, upland NERICA, and others

This site is located on the confluence of the Mankrankese and Mankrankuma and stretches along the Mankrankese stream downslope. The lowland varies in width, stretching about 130-400 metres from the upland-lowland fringes to the stream. Termite mounds commonly occur over the low-lying lands, making the terrain in the valley gently undulating. The dominant soils are *Temang* (Gleysol) and *Kokofu* (Gleyic Lixisol) *series*.

There is a natural spring, though limited in area of influence, can be harnessed into a reservoir for irrigation. This site is not developed into sawah fields but portions are used for rainfed rice production.

"Sawah" fields can be constructed on Temang and Kokofu series. However the numerous termite mounds within the Temang unit will demand a lot of earth movement. Also, Kokofu soil unit, being at the lower slope of the upland is at a higher elevation than the Temang unit in the lowland. To avoid the removal of a bulky soil material, the "sawah" fields on Kokofu will have to be at a higher elevation than the Temang fields.

Adugyama – Dwinyan valley:

Suitable for Irrigated "sawah" by natural spring with other supplementary irrigation

This site is just adjacent to Adugyama settlement. The lowland is confined to the left bank while the right bank rises steeply from the edge of the stream into the upland

A spring originates from the settlement at a location close to the Kumasi – Sunyani trunk road, which has been harnessed into a fish–pond further down and close to the main stream. A large portion of the site has been developed into sawah fields, which are mainly rainfed and some flows coming from the spring upslope to the fields during the peak of the rains.

The soils in the upland comprise Nzima (Ferric Acrisol) and Zongo (Plinthosol) series on middle slopes and Kokofu series (Gleyic Lixisol) in the lower slope. The valley is dominated by Temang series (Gleysol) with a small strip of Kakum series (Gleyic Lixisol).

Adugyama – Gold valley:

Suitable for Rained “sawah” for lowland rice in high rainfall year, but oil palm, cacao, upland NERICA, and others in normal years

This is a first order valley with a narrow low-lying land, measuring between 50 and 100metres in width on the left bank. Sawah fields have been constructed and rice is mainly grown by rainfed water. The valley was virtually dry at the time of the study. However, water can be trapped and diverted onto the sawah fields when flows occur in the rainy season.

The upland soils consist of Nzima / Bekwai series (Ferric Acrisol), Zongo series (Haplic Plinthosol) and Kokofu series (Gleyic Lixisol). The valley is occupied by Temang series (Gleysol).

Biemso No.1(Dyke site):

Suitable for Irrigated "sawah" by pond or dyke with canal

This site occurs on the left bank of the Biem stream. The right bank rises steeply from the edge of the stream. A dyke has been constructed across a point towards the eastern end, where water is transported by canal to sawah field downslope. The rest of the area towards the west is largely undeveloped except a small area of sawah field, which is rainfed.

The upland soils consist of Mim (Endoskeleti-Ferric Acrisol) and Afrancho (Chromic Lixisol) series on middle slopes and Kokofu series (Gleyic Lixisol) on lower slopes. In the valley, the soils consist of poorly drained Temang series (Gleysol) and the terrace adjoining the stream, Kakum series (Gleyic Lixisol).

Biemso No. 1 (Zongo)

Suitable for Rained "sawah" with some natural and artificial water harvesting and supply

This site occurs also on the left bank of the Biem stream with the right bank rises steeply from the edge of the stream at certain areas towards the road to Biemso No. 2. The area is largely undeveloped except a small area of sawah field, which is rainfed.

The upland soils consist of Mim (Endoskeleti-Ferric Acrisol) and Afrancho (Chromic Lixisol) series on middle slopes and Kokofu series (Gleyic Lixisol) on lower slopes. In the valley, the soils consist of poorly drained Temang series (Gleysol) and the terrace adjoining the stream, Kakum series (Gleyic Lixisol). This valley is also characterized by undulations, where depressions are occupied by Gleysols (Temang series) and raised portions by the imperfectly to moderately well drained Gleyic Lixisols (*Kakum series*).

Field work for site selection, surveying and sampling has been collected. Soil maps are currently being drawn while soil samples are still being analysed. Details will be provided in the final report.

4. SOIL FERTILITY AND WATER MANAGEMENT UNDER "SAWAH" SYSTEMS.

Buri M. M., Issaka R. N. Wakatsuki T.

Various options available were explored using different materials and forma, for soil fertility and water management over the period. Below are some of the results of experiments conducted under this activity.

(i) The "Sawah" system of rice production for the lowlands: Determining optimum rates of mineral fertilizers for economic yields.

Introduction

Over supply or under supply of plant nutrients can have negative consequences and hence result in the desired results being not obtained. The principle of balanced fertilization requires that this damaging effect be eliminated through the judicious use of fertilizers in order to sustain an economically viable and environmentally friendly agriculture that will meet the requirements of the future (Ernst and Mutert, 1995). Despite recent efforts at encouraging/promoting increases in production, rice yields per unit area are still very low in Ghana. Among identified causes for the low yields are declining soil fertility and the inability of farmers to use the required quantities of mineral fertilizers.

Rice may benefit from the use of fertilizer to compensate exported nutrients. It is estimated that, for every one tone of rice grain harvested, about 15-20kg N, 2-3kg P and 15-20kg K is removed from the soil. With the introduction of new and high yielding rice varieties, soil nutrient mining will be on the increase when mineral fertilizer additions are absent. Sarfo et al. (1998) noted that for most crops, the best fertilizer type, rate and time of application are not known and that this constitutes a constraint to the use of fertilizer. This study was therefore conducted to (i) evaluate the response of rice to mineral fertilization under the "sawah" system - lowland conditions (ii) to establish optimum levels of these nutrients required for obtaining maximum marginal rates of return on investment, and (iii) confirm that all nutrients (N, P and K) are required

Materials and Methods:

Location: The experiments were conducted at two sites, Adugyama (N 06^{o}, 53' 07.8" and W 001^{o}, 52' 40.1") within the Dwinyan watershed and Biemso No. 1 (N 06^{o}, 52' 53.2" and W 001^{o}, 50' 47.3") within the Biem watershed in 2005.

Management practices.

Land preparation: For each year and site, land was demarcated and cleared of vegetation. After the initial clearing, the sites were ploughed with a power tiller and demarcated into replications by bunding. Replicated plots were flooded, rotivated and puddled using a power tiller and manually levelled using a wooden plank. Each replicate was then divided (use of smaller bunds) into smaller plots (treatments)

*Transplantin*g: Transplanting was manually done at a square spacing of 20 cm x 20 cm and at three seedlings per stand. Seedlings were transplanted at 25days after nursing. Seedlings were transplanted in August of each year.

Fertilization: Mineral fertilizer at the various rates were applied using Urea as N sources, Triple Super Phosphate (TSP) as P source and Muriate of Potash (MoP) as K source. All P and K with 50% N was applied as basal fertilizer, a week after transplanting. The remaining N was applied as topdressing at panicle initiation stage. Each time, fertilizer was applied by broadcast.

Weed control: Weed control was mainly by water (maintaining a minimum water level of between 5-10cm above soil surface). However, there was occasional handpicking of water-resistant weeds.

Harvesting: Harvesting was done manually in December of each year. For each site, a uniform area ($2m^2$) per treatment was used as the harvestable area. Rice was carefully cut up using knives, threshed, winnowed and opened-air (sun)) dried. Grain weights were then taken. Based on such area, grain yield per hectare was estimated.

Statistical analysis. Yield data for the two years were analysed. In each year, ANOVA of paddy grain yield was done for both sites combined and then for each site separately.

Results:

Grain yield response to N: Mineral fertilizer effect on paddy grain yield is shown in Tables 1. Mean grain yield increased significantly with increasing N rates reaching a peak at 90kg N/ha. The same trend was observed at both sites. Paddy grain yields without fertilizer N ranged from 1.47 to 1.48 t/ha. The addition of 30 kg/ha N increased grain yield by 67% (2.94 t/ha). N had significant effect on grain yield up to 90 kg/ha after which the effect was negative.

Table 1: Effect of increasing Nitrogen (N) levels on grain yield (t/ha) at the two sites

Treatment	Site		
(N-P_2O_5-K_2O) kg/ha	Adugyama	Biemso No. 1	Treatment Mean
0-90-90	1.48	1.47	1.47
30-90-90	4.33	4.50	4.41
60-90-90	6.04	6.59	6.31
90-90-90	6.89	7.11	7.00
120-90-90	6.64	6.70	6.67
150-90-90	6.50	6.47	6.48
LSD (0.05) fertilizer	0.61	0.69	0.41
Mean site	5.25	5.47	
LSD (0.05) site	0.24		

Grain yield response to P: In 2005, mean grain yield increased significantly with increasing P levels to 60kg/ha and became similar thereafter. Paddy grain yields without fertilizer P ranged from 2.04 to 2.08 t/ha (Table 2). Similarly, the addition of 30 kg/h P_2O_5 increased grain yield by 51% (2.11/ha).

Table 2: Effect of increasing Phosphorus levels on grain yield (t/ha) at the two sites

Treatment	Site		
($N-P_2O_5-K_2O$) kg/ha	Adugyama	Biemso No. 1	Treatment Mean
90-0-90	2.08	2.04	2.06
90-30-90	4.17	4.17	4.17
90-60-90	8.23	8.17	8.20
90-90-90	6.79	7.11	6.95
90-120-90	7.20	6.98	7.09
LSD (0.05) fertilizer	0.17	0.12	0.92
Mean (site)	5.70	5.70	
LSD (0.05) site	0.58		

Grain yield response to K: A similar increasing trend in grain yield with increasing rates of K was also observed at both locations. Paddy grain yields without fertilizer K ranged from 2.31 to 2.52 t/ha in 2005 (Table 3). In the same light, the addition of 30 kg/ha K_2O increased grain yield by 56% (3.10 t/ha) in 2005. The mean increase from the second increment/level of fertilizer (from 30 to 60) for the three elements was also statistically significant from the first (from 0 to 30).

Table 3: Effect of increasing Potassium (K) levels on grain yield (t/ha) at the two sites

Treatment	Site		
($N-P_2O_5-K_2O$) kg/ha	Adugyama	Biemso No. 1	Treatment Mean
90-90-0	2.31	2.52	2.42
90-90-30	5.40	5.64	5.52
90-90-60	7.82	7.75	7.79
90-90-90	6.79	7.11	6.95
LSD (0.05) fertilizer	0.80	0.67	0.47
Mean (site)	5.58	5.76	
LSD (0.05) site	0.33		

General grain yield response: The effect of not including N, P, or K on grain yield is shown in Table 2. In 2005 all the three elements seriously influenced rice grain yield. The ANOVA for the two sites combined in 2005 showed the effect of fertilizer rates to be highly significant on grain yield. The effect of fertilizer x location interaction were non-significant. Grain yield response to fertilizer attained peak values at 7.04, 7.79 and 8.20 t/ha corresponding to the same fertilizer rates of 90-90-90, 90-90-60 and 90-60-90kg/ha N, P_2O_5 K_2O respectively.

Table 4. Effect of the non-inclusion of a mineral nutrient on grain yield (t/ha)

($N-P_2O_5-K_2O$) kg/ha	Adugyama	Biemso No. 1
0-90-90	1.48	1.47
90-0-90	2.08	2.04
90-90-0	2.31	2.53
90-90-90	6.89	7.11
SE (fertilizer)	1.24	1.29

(ii) Forms of Soil Phosphorus and Phosphorus adsorption of some Inland Valleys in West Africa

Introduction

Presently most West African countries, including Ghana, import over 40% of their rice requirements. Inland valleys have been identified as the ecology if well managed will ensure enough rice for the West African people. Poor water management and the inherent low fertility status of these valleys have been identified as the major causes for low rice yields per unit area. Nitrogen, phosphorus and potassium are the nutrients that are generally required for adequate production of rice. Among all the major nutrients (N, P and K) phosphorus availability is a problem since it can easily be lost through fixation.

Materials and Methods:

The study area, climate and sampling method have been described in Issaka et al (1996).

Laboratory analysis: Total P was determined by complete dissolution of 50 mg soil sample (finely ground) in a closed Teflon with 1.0 ml conc. HCI acid and 0.5 ml HF acid (46-48%) and allowed to stand for at least 16 hrs. 6 ml of boric solution (4%) was finally added and allowed to stand for at least 1 hr to neutralize any excess HF acid (Uchida et al. 1979). The ignition method as described by Saunders and Williams (1955) and modified by Walker and Adams (1958) was used to determined organic P. Sequential fractionation of inorganic P was by the procedure described by Chang and Jackson (1957). In all cases P was determined calorimetrically as described by Murphy and Riley (1962). Dithionate-Citrate-Bicarbonate method was used in determining free Fe and Al oxides based on the method described in IITA (1979) manual. P adsorption studies was according to the method described by Okalebo et al (1993).

Results:

Phosphorus (P) is one of the limiting element in most inland valleys of West Africa. A study on some inland valley soils show that available phosphorus is generally low and ranged from 0.9-29.8 mg P kg^{-1} (Bray P 2). Inorganic P ranged from 122 -419 mg P kg^{-1}. Mean active inorganic P (75 mg P kg^{-1}) was lower than inactive inorganic P (163 mg P kg^{-1}). Organic P ranged from 35-136 mg P kg^{-1} with total P ranging from 174-665 mg P kg^{-1} . Active inorganic and organic phosphorus which affect phosphorus availability are generally low. Inactive phosphorus is relatively high probably due to the highly weathered nature of most of these soils. P adsorption correlated negatively with available P and positively with DCB Fe_2O_3, DCB Al_2O_3 and clay content. Some of the soils show high phosphorus fixation capacities and hence have serious implications regarding phosphorus availability. Significant improvement of soil organic matter, liming of acid soils and judicious use of phosphorus fertilizers are options necessary for the improvement of phosphorus availability in these soils. Use of amendments to reduce adsorption will greatly enhance P efficiency.

Proposed study

Assessing the efficacy of alternative P sorbing soil amendments

Concern over the contribution of agricultural phosphorus (P) to fresh water eutrophication has focused attention on practices that decrease P losses from agricultural soils. Instead of concentrating on only appropriate P rates for increase production, practices that will reduce fixation and ensure efficient P utilization will be encouraged. This study will assesses various readily available materials (such rice husk, rice straw, chicken manure etc) as possible P Sorbing Soil Amendments (PSSAs) by comparing their near- and long-term effects on soil P solubility and potential availability to runoff with their impact on plant available P.

(iii) Response of selected rice varieties to different fertilizer types within the Biem and Dwinyan watersheds.

Introduction

Among identified causes for the low yields are declining soil fertility and the inability of farmers to use the required quantities of mineral fertilizers. Farmers mostly rely solely on natural soil fertility. For any integrated sustainable nutrient management system, plant nutrient supply packages need to be developed and fine-tuned with efficient economic and environmentally sound production principles that lead to proper soil fertility management. In the light of the above, field experiments were conducted to compare the performance of more readily, available and affordable organic fertilizers (poultry manure, hummified sludge) against mineral fertilizer using three rice varieties (Sikamo, Wita 7 and Bouakye 189). the suitability of the technology in a cost effective integrated nutrient management system that can easily be adopted by poor resource farmers.

Materials and Methods:

Location: The experiments were conducted at two sites, Adugyama (N 06^o, 53’ 07.8” and W 001^o, 52’ 40.1”) within the Dwinyan watershed and Biemso No. 1 (N 06^o, 52’ 53.2” and W 001^o, 50’ 47.3”) within the Biem watershed in 2005.

*Management practices***.**

Land preparation: For each site, land was demarcated and cleared of vegetation. After the initial clearing, the sites were ploughed with a power tiller and demarcated into replications by bunding. Replicated plots were flooded, rotivated and puddled using a power tiller and manually levelled using a wooden plank. Each replicate was then divided (use of smaller bunds) into smaller plots (treatments)

Transplanting: Transplanting was manually done at a square spacing of 20 cm x 20 cm and at three seedlings per stand. Seedlings were transplanted at 25days after nursing. Seedlings were transplanted in August of each year.

Fertilization Mineral fertilizer at the rate of 90-60-60 kg N-P_2O_5-K_2O/ha was applied using Urea as N sources, Triple Super Phosphate (TSP) as P source and Muriate of Potash (MoP) as K source. All P and K with 50% N was applied as basal fertilizer, a week after transplanting. The remaining N was applied as topdressing at panicle initiation stage. Hummified sludge was applied at 2 t/ha at a go a week after transplanting. Chicken manure was, however, worked into the soil two weeks before rice seedlings were transplanted. Each time, fertilizer was applied by broadcast.

Weed control: Weed control was mainly by water (maintaining a minimum water level of between 5-10cm above soil surface). However, there was occasional handpicking of water-resistant weeds.

Harvesting: Harvesting was done manually. For each site, a uniform area ($2m^2$) per treatment was used as the harvestable area. Rice was carefully cut up using knives, threshed, winnowed and opened-air (sun)) dried to 14% moisture level. Grain weights were then taken. Based on such area, grain yield per hectare was estimated.

Statistical analysis. Yield data for the two years were analysed. In each year, ANOVA of paddy grain yield was done for both sites combined and then for each site separately.

Results:

Results show that there were no significant differences in grain yield when the three different fertilizers types were used at Biemso 1. Poultry manure, however, significantly out yielded both mineral fertilizer and hummified sludge at Adugyama (Table 1). Location did not also significantly affect grain yield. The interaction between location and fertilizer type was also insignificant. There were, however, significant differences in grain yield between the different rice varieties (Table 2). Wita 7 significantly out yielded both Sikamo and Bouakye 189 at both sites. Both location and variety/location interaction were insignificant on variety

The results suggest that the "sawah" technology offers a good option for the improvement of farmers' circumstance under a sound environmental condition

Table 1. Effect of fertilizer type on rice grain yield (paddy) in tones per hector

	Location		
Fertilizer type	Biemso 1	Adugyama	Fertilizer Mean
Chicken Manure	6.90	6.25	6.58
Hummified sludge	5.97	6.52	5.94
Mineral fertilizer	6.40	5.10	5.75
LSD (0.05) fertilizer	1.32	1.81	1.28
Mean (site)	6.42	5.76	
LSD (0.05) site	1.04		

Table 2. Effect of variety on rice grain yield (paddy) in tones per hector

	Location		
Rice variety	Biemso 1	Adugyama	Variety Mean
Sikamo	5.42	4.26	5.71
Wita 7	7.70	7.00	7.35
Bouakye 189	6.18	4.27	4.80
LSD (0.05) variety	0.70	3.05	1.35
Mean (site)	6.38	5.55	
LSD (0.05) site	1.10		

The Way Forward:

organic manures have proved over the years to be quite sustainable as qood nutrient source for rice production. However, age and type of material used as bedding vary greatly and significantly influence nutrient levels. There is therefore the need to look at possible sources of chicken manure and characterize them accordingly for the ultimate benefit of the farmer.

(iv) Effect of the "Sawah" system on yield and nutrient maintenance in selected Inland Valleys

Introduction

In developing an integrated sustainable nutrient management system, efficient, economic and environmentally sound production principles that lead to proper soil fertility management practices are necessary. This was one of the reasons for the introduction of the "sawah" (bunded, levelled and puddle fields) system of rice production for the lowlands. In this light, grain yield and soil fertility levels were monitored over a period to (i) determine the immediate effect of the system on rice grain yield (particularly among farmers) and (ii) to determine the system's influence on improving and/or maintaining soil fertility levels

Materials and Methods:

Location: The study was conducted at Adugyama , Biemso No. 1, Biemso No. 2 and Fedeyeya villages all in the Ahafo Ano South District of Ashanti

Grain yields and soil fertility levels of seven farmer groups were monitored over a period. For each year, samples of rice were taken from farmers, fields, threshed, winnowed, sun-dried and weighed. Total grain yield was then estimated based on the area cropped by each farmer-group.. In the same way, soil samples were collected annually from each site for laboratory analysis to determine fertility levels. Samples were collected each year after crop harvest

Laboratory Analysis: Composite soil samples (0-15 and 15-30 cm depths) per site were collected after land clearing. Samples were air dried, ground and passed through

Results:

Results show that the “sawah” technology has brought about tremendous improvement in rice yields. In the first year, there was more than fourfold increase in rice yield. Grain yield (paddy) increased from less than 1.0 t/ha under the traditional system to more than 4.0 t/ha under the “sawah” system. For the past four years average grain yield showed an increasing trend; 2001, 4.1 t/ha; 2002, 4.3 t/a; 2003, 5.3 t/ha; 2004, 5.5 t/ha and 2005, 5.0t/ha. During the period, the “sawah” system showed a potential of being an efficient nutrient replenishing mechanism. Even though farmers use minimum amounts of mineral fertilizer, topsoil (0-30cm) fertility levels showed that some nutrients had improved while others were sustained.

Way forward:

There is the need to continue this activity for two more years in order to have complete data to cover 4 to 5 continuous years. Such data will help assess better the positive impact of the “sawah” system on soil fertility maintenance, soil conservation and erosion control.

DEVELOPMENT OF SUSTAINABLE RICE-BASED CROPPING SYSTEMS IN THE INLAND VALLEYS OF THE FOREST ZONE USING THE SAWAH TECHNOLOGY.

E. Annan - Afful

Introduction

With population growth, there is the need to produce more food to feed the ever-increasing population. This puts more pressure on the land, especially in areas where slash and burn is the predominant agricultural practice. Recently, the value of inland valley ecosystems in crop production is being emphasized particularly for rice and rice-based cropping systems in West Africa due to its water potential. Increasing agricultural productivity through the use of improved farm management practices by resource poor small-holder farmers, help to create employment and wealth to alleviate poverty in the rural communities.

In Ghana, about 83% of locally produced rice is from the inland valleys. Although the inland valley is a major ecology in rice production, a common feature is that the inland valley rice production system is dominated by small holder resource poor farmers who, faced with numerous production constraints could only manage an average rice yield of about 1.6 t/ha out of the achievable yields of between 4.0-7.2 t/ha per season under good soil and water management (sawah) using improved varieties, good land preparation, seeding method, good nutrient management, appropriate cropping system and pest management technologies.

Presently, less than 10% of the 700,000ha of the potential area for small scale sawah in the inland valleys are cultivated in Ghana. Inland valleys offer considerable potential for agricultural intensification and diversification because dry season, vegetables can be grown on residual soil moisture.

There is therefore the need to fashion a well tailored strategy that will properly address the above mentioned constraints to enhance productivity.

The overall goal is to contribute to food security and poverty reduction by increasing rice production to the level of self-sufficiency. Specifically, to development of appropriate technologies for sustainable rice-based cropping system under rain-fed lowland conditions. The project when completed is expected to result in Improved pre-rice and post-rice based cropping system involving legumes and vegetables developed

Methodology:

A suitable site was selected at Potrikrom in the Ahafo Ano South district of the Ashanti Region. The land was slashed and burnt and the thrash collected (Fig. 1).

Land preparation including ploughing, puddling and leveling was undertaken (Fig. 2). Bunds were also constructed to conserve water.

Three improved rice varieties (Sikamo, Digang and ITA 320) of early, medium and late maturity periods respectively were used. Three improved cowpea varieties of early, medium and late maturity periods respectively were planted. An improved early maturing okra variety was also used.

Design:
The design was a split plot and replicated 3 times

*Main plots***:** Rice varieties; *Sub-plots***:** Cropping sequence

1. Rice - ratoon-early cowpea
2. Rice - ratoon-medium cowpea
5. Rice – medium cowpea
6. Rice – late cowpea

3. Rice - ratoon-late cowpea 7. Rice - okra
4. Rice – early cowpea

Plot Size:5m x 3m. Alley ways: 1m between plots and blocks

*Seeding methods***:**

Rice: Nursery was prepared and the seedlings were transplanted at 21 days after nursing at 20cm x 20cm at 2 seedlings per hill (Fig 3).

Seeding methods for Post-rice crops

Cowpea: 2 plants per hill at 60cm x 20cm; **Okra:** 1 plant per hill at 40cm x 20cm

Fertilizer application: P and K was applied as basal at planting of main rice crop and N was split applied (50% each) at maximum tillering and panicle initiation stages after weeding

Weeding: Weeding was done two times before harvest.

Data collected: Soil sampling was done at the beginning of the experiment and after harvest of the main rice crop. Soil samples will also be collected at the end of the experiment. Plant height, number of tillers, number of panicles per m2, weeds, 1000 grain weight, grain yield of rice, measurement of yield attributes and yield of cowpea and okra and input and output cost will also be measured for cost/benefit analysis.

Harvest; Harvesting of the main rice crop was done by cutting at 25cm height. This height was selected because of the ratoon treatments. The rice was threshed, winnowed and dried.

Results**:**

Yield of main rice crop and ratoon is presented in Table 1. The initial goal of the project to obtain higher rice yield was observed with all the three varieties yielding more than 5t/ha. The ratoon which used residual moisture and took a shorter period to mature yielded an average of approximately 1t/ha for all the varieties. On plot basis, some varieties were able to yield about 1.4t/ha, which is equivalent to the main rice yield of the traditional farmers (1-1.6t/ha). The significant improvement in yield of rice due to the interventions introduced is encouraging and it is interesting to find out the effect in combination with the post-rice crops.

Harvesting of the post-rice crops have started and not completed and it is necessary to combine all the parameters taken and subject to statistical analysis to make a conclusion. The sustainability of the interventions need to be tested for about five years and also introduce to other ecologies.

Table 1. Average yield of main rice and ratoon

Rice Variety	Average yield of main rice (t/ha)	Average yield of ratoon rice (t/ha)
Sikamo	5.97	0.87
Digang	5.39	0.76
ITA 320	6.97	0.94

Way Forward:

The experiment is going to be repeated in year 2006 at Potrikrom. Since this is the first year of the execution of the trial, the results must be confirmed in the second year before the selected appropriate technology is transferred to the farmers field. This will also allow for the determination of the effect of the various treatments in year 2005 on the succeeding rice crop in year 2006.

DEVELOPMENT:

The transfer of the “sawah” technology to rice farmers through the provision of technical services and on-the-job training were intensified during the year. It is interesting to note that the IVRDP is adopting fully the “sawah” technology of rice production. Some of the farmers trained under the “sawah” project are currently playing key roles (lead farmers, seed growers etc) in the execution of the IVRDP.

Way forward:

Train farmers on power tiller operation in particular and general sawah deveopment as some of the newly formed groups have not yet grasp the principles of operating the power tiller and general “sawah” maintenance

PROPOSED AREAS OF FURTHER STUDY AND DATA COLLECTION.

1. Hydrological Flow Characteristics Of Various Rivers In Benchmark Sites:

It is recommended that the study be repeated for three more seasons to subject the data collected to statistical analysis using the different seasons as replicates for different sites and to also get a rough idea about the recurrence of peak flood events for designing the type of weir.

2. Lowland Characterization Of Benchmark Sites For Various Potential "Sawah" Development.

Soil samples are still being analysed in the laboratory. After soil maps have been produced, there may be the need to have them digitised on the GIS system for future use. In addition, a handbook/memoir for each type of “sawah” systems need to be developed for the use of farmers, scientists and land owners. This will also be an effective tool of propagating the “sawah” technology

3. Soil Fertility And Water Management Under “Sawah” Systems:

(a) Assessing the efficacy of alternative P sorbing soil amendments

Concern over the contribution of agricultural phosphorus (P) to fresh water eutrophication has focused attention on practices that decrease P losses from agricultural soils. Instead of concentrating on only appropriate P rates for increase production, practices that will reduce fixation and ensure efficient P utilization will be encouraged. This study will assesses various readily available materials (rice husk, rice straw, chicken manure etc) as possible P Sorbing Soil Amendments (PSSAs) by comparing their near- and long-term effects on soil P solubility and potential availability to runoff with their impact on plant available P.

(b) Fertility characterization (nutrient quality) of organic manures

Chicken manure and others Organic manures have over the year proved sustainable as good nutrient sourcesfor rice production. Even though these material are abundant in southern Ghana, age and type of material used as bedding vary greatly and significantly influence nutrient levels. There is therefore the need to look at possible sources and characterize them accordingly for the ultimate benefit of the farmer.

(c)Effect of the “Sawah” system on soil fertility maintenance, erosion control and Inland Valleys

There is the need to continue this activity for two more years in order to have complete data to cover 4 to 5 continuous years. Such data will help assess better the positive impact of the “sawah” system on soil fertility maintenance, soil conservation and erosion control.

4.Development of Sustainable Rice-based Cropping systems in the inland valleys of the forest zone using the sawah technology:

The experiment is going to be repeated in year 2006 at Potrikrom. Since this is the first year of the execution of the trial, the results must be confirmed in the second year before the selected appropriate technology is transferred to the farmers field. This will also allow for the determination of the effect of the various treatments in year 2005 on the succeeding rice crop in year 2006.

5. Manual For Inland Valleys “Sawah” Development And Rice Cultivation:

Requires updating/grading of information on the submitted draft. Not much information on certain areas was provided in the first draft. Work to continue to fine tune the information to bring it up too the standard of complete manual

6. Farmer Training under Development:

Train farmers on power tiller operation in particular and general “sawah” development of the newly formed groups have not yet grasp the principles of operating the power tiller and general “sawah” maintenance