COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

SOIL RESEARCH INSTITUTE

(CSIR - SRI)

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LIST OF ACRONYMS

ANOVA	-	Analysis of Variance
CEC	-	Cation Exchange Capacity
CSIR	-	Council for Scientific and Industrial Research
CSIR-CRI	-	CSIR – Crops Research Institute
CSIR-FORIG	-	CSIR Forestry Research Institute of Ghana
CSIR-SARI	-	CSIR – Savanna Agricultural Research Institute
CSIR-SRI	-	CSIR – Soil Research Institute
EDIF	-	Export Development and Investment Fund
FDLAR	-	Department of Agricultural Land Resources, Federal Ministry of Agriculture and Rural Development, Nigeria
IFDC	-	International Centre for Soil fertility and Agricultural Development
INM	-	Integrated Nutrient Management
JIRCAS	-	Japan International Research Centre for Agricultural Sciences
KNUST	-	Kwame Nkrumah University of Science and Technology
MoFA	-	Ministry of Food and Agriculture, Ghana
NUE	-	Nutrient Use Efficiency
PISCES	-	Policy Innovation Systems for Clean Energy Security
PRA	-	Participatory Rural Appraisal
QUEFTS	-	Quantitative Evaluation of the Fertility of Tropical Soils
RTIMP	-	Root and Tubers Improvement and Marketing Programme
SAR	-	Sodium Absorption Ratio
UDS	-	University of Development Studies

EXECUTIVE SUMMARY

The Research and Development (R&D) effort of the CSIR-Soil Research Institute continued to focus on the generation of information and technologies for the sustainable management of Ghana's soil resources as captured under the following four main research programmes during the year under review:

The **Soil Classification and Land Evaluation Programme** continued to execute phase 1 of the West African Agricultural Productivity Project (WAAPP) funded project on analogue soil maps digitization and associated establishment of a Geodatabase at the CSIR-SRI. Other soil and land evaluation investigations were also undertaken for various clients. The **Soil Fertility Management Programme** undertook studies on integrated soil fertility management and general cropland productivity enhancement practices for the production of lowland rice, yam, plantain and maize in Ghana. The programme also investigated the potential of Biochar in cropland management for sustainable agriculture. The impact of pesticides on some soil physico-chemical parameters and water quality also received attention in collaboration with the CSIR-FORIG. The **Environmental Management and Climate Change Programme** undertook studies to monitor Lead and Cadmium pollutions in Ashanti region. Higher levels of lead and cadmium beyond the maximum acceptable levels occurred in both soil and water samples at sites close to refuse dumps and lead acid legacy sites. **The Laboratory Analytical Services Programme** continued to receive for analyses soil, water, plants and fertilizer samples from research institutions as well as from private commercial farms, governmental and non-governmental organizations. The laboratories also provided on-the-job training on standard laboratory practices for graduate and undergraduate students from both local and international institutions. In all 7000 samples were analyzed during the period.

Total receipts of Ghana Government funds for the year was GH¢ 4.7 million constituting about 50% of the approved budget whilst the Institute's research commercialization activities yielded GH¢ 79,152.63 mainly from laboratory analytical services and land evaluation consultancy services.

The Institute's staff strength stood at 294, made up of 33 senior members, 85 senior staff and 176 junior staff.

1.0 INTRODUCTION

The year 2012 witnessed a sustained effort in pursuing the institute's mandate of generating scientific information and technologies for effective planning, utilization and management of the soil resources of Ghana for sustainable agriculture, industry and environment, Research activities during the year consisted of the following programmes:

- o Land Evaluation
- o Soil Fertility Management
- o Soil and Water Management
- o Environmental Management and Climate Change
- o Laboratory Analytical Services
- o Training/Technology Transfer.

The research and development (R&D) effort of the institute were undertaken with the aim of achieving the following research objectives:

- § Develop knowledge for efficient management of the soil resources of Ghana.
- § Strengthen the Institute's delivery capacity for increased agricultural production.
- § Establish and strengthen linkages with local and international organizations.
- § Develop and promote sound and safe environmental practices.
- § Commercialize soil resources research findings and services.

In line with the above objectives, R&D effort yielded the production of numerous scientific publications in renowned peer reviewed journals. The Institute's scientists also participated in several conferences, workshops, field demonstrations, exhibitions and fairs to promote sustainable soil resources management technologies.

2.0 RESEARCH PROGRAMMES

2.1 SOIL CLASSIFICATION AND LAND EVALUATION PROGRAMME

2.1.1 Study Title: Soil map digitization and report production for soil survey regions and districts in Ghana. (Research contract NCRG NO. 017-CSIR/WAAPP)

Research Team: J.K. Senayah, E. Amoakwa, K.A. Nketia, J. Awoonor, E. Asamoah, J. Badu, A. Boafo, A. Appiah.

Source of Funding: WAAPP

Duration of Project: 2010-2013

Introduction

In the recent past, maps on the Soil Survey Regions of Ghana at Kwadaso - Kumasi, were manually drawn. The WAAPP Projects (Research contract NCRG No. 016 and No. 017) resulted in the creation of a geodatabase for soil resource inventories. The digitization of soil maps of the thirty-five (35) Soil Survey Regions of Ghana were embarked upon which have resulted in the subsequent updating of soil resources for the various districts at a semi-detailed scale of 1:50,000 – 100,000. The project started in 2010 with the set-up of a GIS unit (WAAPP/NCRG/016). The purpose of this report is to provide information on work done so far.

Objectives

The objectives of these two projects (WAAPP/NCRG/016 & 017) are to:

i. Create a digital catalogue (geodatabase) of all maps and reports available in CSIR-Soil Research Institute
ii. Migrate the Institute's traditional map making onto digital platforms
iii. Update soil maps of the detailed reconnaissance soil surveys so as to generate soil maps at a scale of 1:50,000 – 100,000.

Implementation

- Objectives (i) and (ii) have been completed

- Objective 3 is 90% completed with respect to the reconnaissance soil surveys while the district soil mapping is about 5% completed.

The implementation of objectives 1 and 2 were facilitated by (a) the use of the regional soil survey reports/memoirs (1:250,000) as base information. (b) topographical/relief maps at a scale of 1:50,000 acquired from the Survey Department of Ghana (c) Field checks on existing/identified soil units with the assistance of GPS and digital elevation model (DEM). Soil scientists were able to identify and map highlands from the lowlands as well as from middle slopes (d) Soil profile description, classification and suitability assessment of the major soils for crop production and management were carried out.

Currently Activities

1. Soil mapping of the districts

Four (4) districts (Wenchi Municipal, Afigya-Kwabre District, Tain District and Gomoa-East Districts (figures 1, 2, 3 & 4) have so far been completed out of the 275. Outputs include; soil map, soil suitability map that evaluates and group soil units with similar limitations and management practices. Digital elevation model and other resources were also identified in the course of the study.

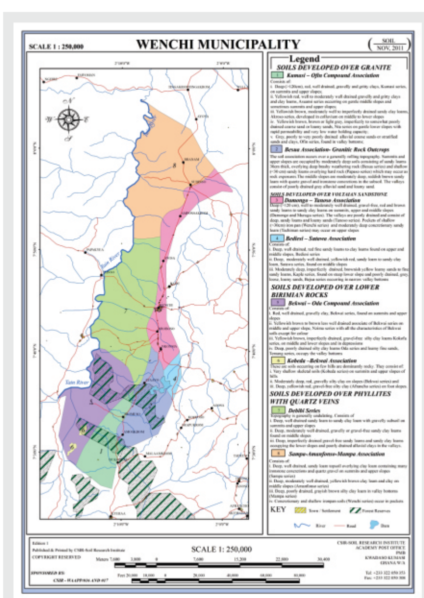

Figure 1: Soil Map of Wenchi Municipal

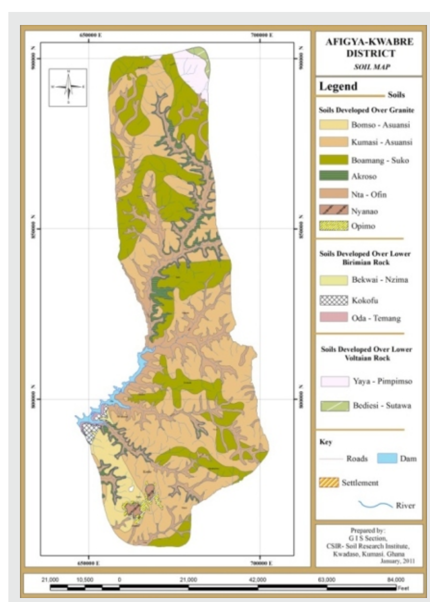

Figure 2: Soil Map of Afigya Kwabre District

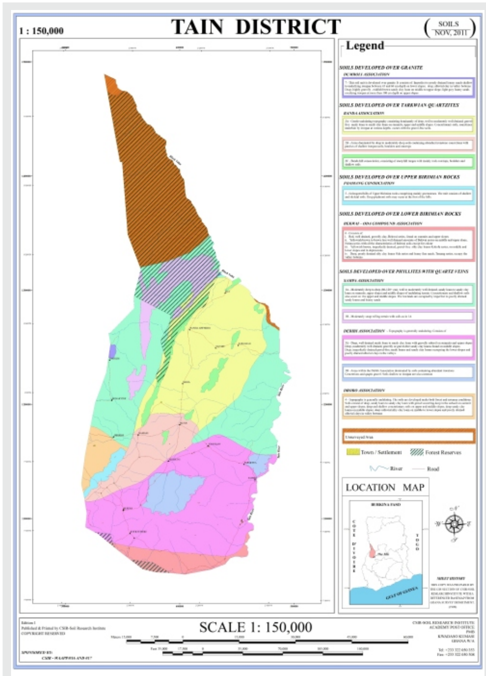

Figure 3: Soil Map of Tain District

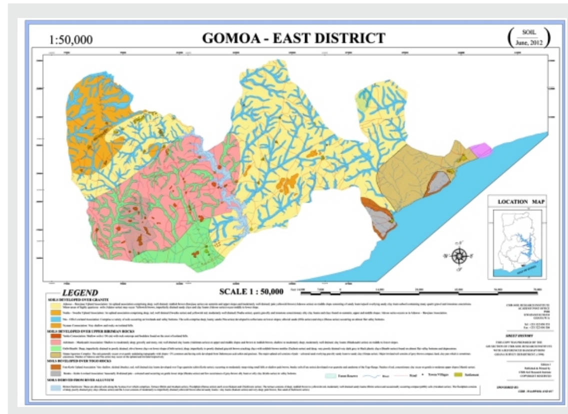

Figure 4: Soil Map of Gomoa East District

2. *Soil Survey Regions*

There are about thirty-five (35) soil survey regions delineated by CSIR-Soil Research Institute. Twenty-two (22) have been digitized. The digitized regions are;

- Afram Basin
- Ayensu-Densu
- Ochi-Nakwa Basin
- Pawnpawn Basin
- Pra Basin
- Pru Basin
- Yapei-Sawla Basin
- Kumasi Region
- Ankobra Basin
- Lawra-Wa Basin
- Bia Basin
- Dayi-Asukawkaw Basin
- Accra Plains
- Navorongo-Bawku Region
- Cape Coast Region
- Birim Basin
- Upper Tano
- Lower Tano
- Upper Oti Basin
- Lower Oti Basin
- Sene-Obosum
- Kintampo-Yeji

Uncompleted basins to be digitized are;

- Daka
- Sissili
- Sorri
- Mole
- Daboya
- Tamale North
- Tamale South
- Upper Kulpawn
- Lower Kulpawn)

The uncompleted ones include basins where formal soil survey at the detailed reconnaissance level (1:250,000) have been undertaken and report not yet written or have not been carried out at all. The former include Upper and Lower Oti Basin and the latter also include Tamale Region, Kulpawn, Sisili, and Daka Basins.

Conclusion

A great potential exist in digital soil mapping because it improves the consistency, accuracy and speed at which soil survey information is created. These techniques can be applied to update existing soil survey information and the creation of soil inventories for unmapped areas. The beneficiaries of this project are: CSIR-Soil Research Institute, Governmental organizations, CSIR- Crops Research Institute, Ministry of Food and Agriculture (MoFA), Non-Governmental Organisations (NGO's), Universities, and Investors.

2.1.3 Study Title: Soil and Landuse Evaluation for Sustainable Agriculture in the Forest Savannah Transition Zone of Ghana.

***Research Team*:** J. Awoonor and Ó. Arnalds
***Source of Funding*:** UNU-LRT Project work
***Duration of Project*:** 2012

Introduction

Ghana, is a tropical country divided into three broad ecological zones namely; Forest, Forest – Savannah Transition and Savannah Zones. In between the Forest and Savannah zones lies the Forest Savanna Transition Zone (FSTZ) which is a blend of the forest and savannah zones. The total annual rainfall in Ejura is 1400 mm and 1200 mm at Atebubu both within the FSTZ. Temperatures within the study area are uniformly high throughout the year with yearly averages of around 33°C maximum and 20.2°C minimum (Ghana Meteorological Service Department, 2000). Agriculture is the main source of livelihood. About 60% of the population dwell in rural communities and engage in subsistance agriculture (smallholder farmers) of which majority are women (Ghana Statistical Service (GSS), 2010).

Problem Statement

The major cause of declining soil fertility is inappropriate land use. Population of the study area was 81, 115 in 2000 and 101, 826 in 2010 which implies there has being a 20.3% increase within a ten year period (Ghana Statistical S, 2010). Pressure on land and soil resources in the district has resulted in unsustainable agricultural practices; (overgrazing, overharvesting of fuel-wood, uncontrolled bush burning, reduction in the length of fallow periods, settlement expansion etc). Hence, a decline in soil fertility.

Declining soil fertility implies not only less food is produced, but also production of cash crops and incomes are adversely affected.

Objectives

- The aim of the study is to establish the inherent soil fertility status and to introduce land use management strategies to improve livelihood of small holder farmers in Ejura – Sekyedumasi District

- Specific objectives are to;
  - I. Determine soil fertility decline in Ejura - Sekyedumase District),
  - ii. Identify the various causes of soil fertility decline,
  - iii. Explore measures to mitigate soil fertility decline,
  - iv. Recommend land - use management strategies to sustain crop production.

The key research question is to investigate differences in key soil parameters in soils of the Ejura-Sekyedumase district under the three different land use types: forest reserve, cultivated land and savannah regrowth. These soil parameters are % Total carbon, % total nitrogen, soil pH, C: N ratio, bulk density, cation exchange capacity, base saturation, potassium, phosphorus and total carbon stocks.

Methodology

Soil samples were obtained from 68 sites. Land use type was classified as Forested area – 20 samples, Savannah regrowth – 24 samples, and Cultivated land – 24 samples. Soil samples at each location were sampled using an auger along the catena spanning from the summit to the valley. At examination points, auger bores (5cm diameter) were taken to identify and describe soil type. Soil depth, texture, drainage and coarse fragment (gravel and stones) were parameters considered on the field to characterize soil types according to the local classification system. The soils were also classifield based on the FAO classification (FAO-WRB Classification; IUSS Working Group WRB 2006). Information about vegetation, climate and landuse was also collected in the field.

GPS co-ordinates were taken at each observation point for mapping. A digital soil map of the area obtained from CSIR – Soil Research Institute, was overlaid on the data collected with GPS to check the accuracy of the identified soil types using ArcGIS 10 software. Soil samples taken to the laboratory were air dried and sieved (2mm) and analysed for soil pH, organic carbon, total nitrogen, bulk density, cation exchange capacity and available phosphorus and potassium.

Results

The results for soil parameters for each of the land use types are presented in Tables 1 and 2.

The numbers are weighted average. There is a marked difference in pH between landuse types. with pH being highest in the forest soils (6.4) but lower in the cultivated(5.8) and savannah soils (5.9).

Table 1. Average values (mean±standard deviation) for soil pH, % organic carbon (C), nitogen (N), C:N ratio and bulk density (BD).

Landuse Type	Sample Size	Top soil (0 – 20 cm) Mean				
		pH	% OC	% N	C:N	BD(g/cm^3)
Forest Reserve (FR)	20	6.4±0.6	1.7±0.3	0.2±0.1	11.4±2.7	1.3±0.0
Cultivated Land (CL)	22	5.8±0.9	0.9±0.6	0.1±0.2	9.9±4.4	1.4±0.1
Savannah Regrowth (SR)	20	5.9±0.7	1.1±0.6	0.1±0.2	11.7±4.0	1.4±0.0

Table 2 shows that CEC in the top 20 cm decreased from 13.9 to 10.4 to 6.1 in the forest reserve, cultivated land and the savannah regrowth respectively.

Table 2. Average values (mean±standard deviation) for cation exchange capacity (CEC), base saturation (BS),phosphorus (P) and potassium (K) of soils in the Ejura-Sekyedumase district.

Landuse Type	Sample Size	Average in top soil (0 – 20 cm)			
		CEC [Cmol(+/kg)]	%BS	P	K
Forest Reserve (FR)	20	13.9±6.4	95.4±8.9	8.3±1.2	0.9±0.2
Cultivated Land (CL)	24	10.4±13.4	64.6±24.1	5.2±1.7	0.6±0.2
Savannah Regrowth (SR)	24	6.1±3.1	72.4±13.6	8.4±0.9	0.9±0.1

Discussion

Organic carbon and nitrogen

The results show that there is more organic carbon in the forest reserve than the cultivated land (Table 1). The high organic carbon content observed in the forest reserve is attributed to the decomposition of fallen leaves and dead branches by soil fauna in the soil medium. In the forest reserve, the micro - climate needed for nutrient transformation is very favourable, and for that reason, the decomposition of organic material is enhanced. Additionally, the numerous fine roots in forest are known to be the main source of carbon additions to soils, whether through root turnover or via exudates by mycorrhizal fungi in the rhizosphere (Price et al, 2012).

It was generally observed that organic carbon, nitrogen, pH, P, K, and CEC contents were lower in the savannah and cultivated soils than in the forest reserve soils. Price et al. (2012) had a similar observation and noted that carbon is lost from surface organic matter as CO_2 by microbial respiration, and therefore, by mixing and incorporation of surface organic matter into mineral soil horizons by soil fauna and by leaching of dissolved organic matter (DOM).

Soil pH is an important factor in determining the fertility status of soils. pH values in the soils studied were in the order of forest reserve > savannah regrowth > cultivated land (Table 1). Continuous cropping has resulted in a decrease in soil pH.

Conclusion

Conversion from natural (FR) to agricultural ecosystems (CL) changes the amount of soil organic carbon pool which also affected soil fertility in the study area. Comparing the average carbon stocks of the forest to cultivated lands, there has been a significant loss of soil nutrients in the cultivated fields hence a decline in soil fertility. The Degradation Index for the cultivated land (53.4%) as compared to the forest reserve and the savannah regrowth (64.86%) also proves that soil fertility has declined.

References

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Price, S.P., M. A. Bradford, and M. S. Ashton. 2012. Characterizing organic carbon stocks and flows in forest Soils. Pages 1-24 in M. S. Ashton, M. L. Tyrrell, D. Spalding, and B. Gentry, editors. Managing forest carbon in a changing climate. Springer, New York.

2.1.4 Study Title: Soil Suitability Assessment for Oil Palm Cultivation at Akaa near Jasikan in the Volta Region, for SG Sustainable Oil, Ghana Ltd.

Research Team: E. Boateng, P. M. Gyekye Jnr., E. Akuffo and T. Ayamga
Source of funding: SG Sustainable Oil, Ghana Ltd
Duration of Project: 4 months
Year: 2012

Introduction

This report is based on a request by SG Sustainable Oil Ghana Limited to the Soil Research Institute to investigate the soils on a parcel of land (approximately 1,757 hectares) at Akaa near Jasikan in the Volta Region, for oil palm production.

Objectives

The objectives of the soil investigations were to identify, describe and map out the different soil types of the area, determine the general fertility status of the soils, and the suitability of the soils for oil palm production and provide recommendations for improved fertility management to enable high and sustained oil palm yields.

Methodology

A detailed soil survey was carried out to obtain optimal data at reduced cost. The specific activities include: Base information on climate, topography, vegetation, geology and soils of the area from secondary data (reports, maps, soil surveys etc. available at the Soil Research Institute and elsewhere), were gathered. A site map based on a Ghana Soil Association map from CSIR-SRI, a 1:50 000 topographic map from the Survey Department and a digital outline of the site supplied by the client using Arcmap software was also prepared. This was followed by consultations with the Chief and people of Akaa for the necessary protocols.

Field studies involved field inspection, semi-detailed soil survey and sampling of soils. A few pillars erected at the vertices of the base map were identified. Traverses were cut perpendicular to the baseline at 90^{o} (MN) and 270^{o} (MN) at 400 m intervals. Inspection holes were dug at every 100m along the traverses to describe and identify each soil series, using chisels and augers. Parameters observed included, depth, texture, drainage, colour, coarse-fragment content, water table and land use. Bulk density samples were also taken from the profile pits.

The coordinates of each chisel/auger point were recorded by GPS. The soil types were identified, recorded and later plotted on a base map and interpolation carried out to obtain a soil map. After this, checking was done for soil boundaries by digging some additional chisel holes at shorter intervals to establish more firmly the approximate positions of the soil boundaries.

For a more detailed characterization of the soils, a total of 8 profile pits spread over the entire land, were dug as representative soil series and described, based on the FAO (1990) soil profile description. Soil samples were taken at each genetic horizon for chemical and physical analysis. The profile pits were described according to the international guidelines prescribed by the FAO (FAO/ISRIC, 1990). The Munsell Colour chart (1994 revised edition) was used in determining the soil colour. Soil texture was determined by manipulative test and feel. Soil profile samples were taken according to pedogenetic horizons for laboratory analyses.

Laboratory analyses to assess the status of the fertility, chemical and physical properties of the soil was carried out. Laboratory analyses were carried out on air-dried, crushed and sieved fine earth fraction of (< 2 mm soil) samples. The soil chemical properties were rated according to classes described in FAO (1984) for soil reaction, Landen (1991) for exchangeable Mg, and Arcia et al., 1995) for other parameters.

Result

The soils found at the site falls within the Adomi-Kpeyi Compound Association. This association is made up of Upland drift soils (*Afeyi* and *Kpandu series*), which have been developed in piedmont drift materials and occur on upper and middle slopes of gently undulating relief. Soils derived from the remnants of the former erosion surfaces (*Jana series*) and occurring on lower slopes are shallow to moderately shallow and concretionary and colluvia-alluvial soils occupying valley bottoms (*Kpeyi* and *Oku series*).

Also encountered at the western and south-eastern portions were *Chichiwere* series. This soil consists of very deep, yellowish brown or pale brown, loose loamy sand; or sandy light loam developed in old sandy alluvial along the banks of the major rivers within the area, and occurs in areas above flood level. Additionally, due to erosion processes overtime, soils of most portions of the area have been denuded, exposing ironpan above surface level forming shallow and concretionary soils (*Kpelesawgu* and *Wenchi* series).

The pH of the soils range from moderately acid to slightly acid (5.1 – 6.1 pH). Organic carbon content range from low to medium (0.5 – 1.9%). Total nitrogen level is also generally very low to medium (0.04 – 0.17%). Available phosphorus and potassium are all low (4.2 – 9.7mg/kg and 19.4 – 29.4 mg/kg, respectively). Exchangeable cations are either low or very low (1.1 – 0.07cmol(+)/kg) except sodium which is medium {0.50cmol(+)/kg on average}. The effective cation exchange capacity (ECEC), therefore, is also low {2.6 - 6.3 cmol(+)/kg}.

The current and potential suitability ratings of the soils for oil palm is such that *Jana* series (occupying about 63% of the total area) and *Kpandu* series (18% of area) are marginally suitable (S3f rating), but can be improved to moderately suitable (S2i rating) upon manure/fertilizer application. Similarly, *Afeyi* series (7% of area) and *Oku* series (1% of area) are currently marginally suitable (S3tf and S3wf respectively). However, both have the potential of being improved to moderately suitable (S2i rating) after manure/fertilizer application (Table 3). *Chichiwere* series and *Wenchi* series occupy very small portions of the study area, and are marginally to unsuitable for oil palm cultivation.

Table 3. Current and potential suitability ratings for oil palm.

Soil series	Extent Ha	Extent %	Current rating	Recommendations	Potential rating after adoption of interventions	Remarks
Jana	1,105	62.78	S3f	Manure/fertilizer application	S2i	Slow internal drainage below concretionary zone. Soil has moderate water holding capacity
Kpandu	311	17.67	S3f	Manure/fertilizer application	S2i	Plant-soil moisture relationship may be affected during prolonged dry season
Afeyi	117	6.65	S3tf	Manure/fertilizer application	S2i	Plant-soil moisture relationship poor during dry season.
Oku	24	1.39	S3wf	Manure/fertilizer application	S2i	Soils are seasonally drained and subject to seasonal water logging
Kpeyi	144	8.21	S3twf	Manure/fertilizer application	S2wi	Soils are seasonally drained and subject to seasonal water logging
Chichiwere	3	0.16	S3tf	-	S3tci	Excessively well drained leading to low moisture retention and nutrients
Wenchi	55	3.14	Nr	-	Nr	Very shallow depth, cannot easily be corrected

Conclusion and Recommendations

The results of the soil suitability assessment showed that currently all the soils with the exception of *Wenchi series* are marginally suitable for oil palm cultivation. *Wenchi series* is not suitable for crop production due to a severe limitation of depth due to iron pan sheet. (depth $\leqslant$ 30 cm).

Currently, marginally suitable soils occupy approximately 97% of the area, and unsuitable soils occupy 3% of the area, whiles potentially, a small portion of the area (about 0.2%) is moderately suitable for oil palm cultivation.

The fertility of the soil is generally low to moderate and will require adequate fertilizer application for effective growth and good yield. Fertilizer application rate for the first three years should be 200g/plant of nitrogen, potassium and phosphorus. From the third to the seventh year, fertilizer application rate should be increased to between 500-1000g/plant of N.P_2O_5 and K_2O and 500g/plant of magnesium. Above the 7th year, fertilizer application should be between 1000-1500g/plant of N.P_2O_5 and K_2O and about 1000g/plant of magnesium.

2.2. SOIL FERTILITY MANAGEMENT PROGRAMME

2.2.1 Study Title: **CSIR-Soil Research Institute / Kinki University joint study-New "Sawah" Project**

Research Team: Buri M. M, Issaka R. N. and Wakatsuki T
Collaborating Institutions: Kinki University, Nara-Japan; CSIR-CRI, MoFA
Source of Funding: Kinki University, Japan
Duration of Project: 2012

Introduction

Food security is a major problem which developing countries like Ghana are striving to achieve. This can only be made possible when certain interventions are put in place to ensure and encourage local production of our staple food crops. Rice is one crop whose imports takes a significant portion of Ghana foreign reserves. Consequently, any interventions that will lead to increased production on the local front is welcome. The main goal of the CSIR – Soil Research Institute (SRI)/Kinki University New "Sawah" Project is therefore to develop suitable technologies that will enhance, encourage and sustain rice production within the lowlands across the variable agro-ecological zones in the country. Empowering local farmers to produce more rice will not only reduce imports but create employment avenues for the rural poor and generate income. The New "Sawah" Project's main goal is therefore to encourage local rice production through the transfer of improved production techniques to local farmers.

Methodology

The project continued with its two way approach towards achieving its objectives. Technology transfer through on-the-job-training which involves research to extension, research to farmer, extension to farmer, and farmer-farmer training, while conduct of field research to generate more information that will enhance further technology transfer forms the second.

Results

Over 100 lead farmers and extension staff of the Ministry of Food and Agriculture have been trained to continue to assist in the scaling out of the technology. Farmers who have adopted the technology now obtain yields of up to 8.0 t ha^{-1}. Major activities like field experimentation and data collection were, however, scaled down drastically during the period under review, mainly due to lack of funds.

Proceedings of the International workshop on "the 'Sawah' Eco-technology and Rice Farming in Sub-Saharan Africa" which was organized in Ghana, have been published during the period and copies presented to the appropriate organizations (CSIR Head Office, Ministry of Food and Agriculture, Ministry of Environment, Science and technology, CSIR Institutes, Universities, Agric Colleges and Academy of Art and Science) in addition to individual scientists and persons. A manual on the principles and practices of the technology, as a means of empowering local rice production and increasing productivity is currently being prepared.

Way forward

The "Sawah" eco-technology has got to a stage where its effective scaling out to benefit more Ghanaian rice farmers is necessary. In this direction, a concept note outlining a strategy for its out scaling has been presented to MoFA. The project can play a major role in the capacity building of both MoFA field staff and farmers on the technology. No response has been received yet but the project will continue to dialogue with MoFA on the way forward. This is very important not only for increased productivity and production of local rice but more importantly sustainable utilization of the country's lowlands for self sufficiency in rice production

2.2.2 Study Title: Response of selected rice varieties to low Phosphorus (P) soils in the forest agroecological zone of Ghana

Research Team: M.M. Buri, R.N Issaka and M. Wissuwa

Collaborating Institutions: JIRCAS, Japan; Africa Rice, Benin; MoFA, Ghana

Source of Funding: JIRCAS, Japan

Duration of Project: 2012

Introduction

According to Ghana's Ministry of Food and Agriculture (MoFA-2009), rice has become the second most important staple food after maize in the country and its consumption keeps increasing as a result of population growth, urbanization and change in consumer habits. MoFA estimated per capita consumption in 2010 to be 41.1kg which will rise to 63.0kg by 2015. MoFA further indicated that based on population growth, the current demand of about 500,000 tons of rice per year will increase to over 600,000 tons per year by 2015. Currently, Ghana depends largely on imported rice to make up for the deficit in domestic rice supply with, annual average imports of about 400,000 tons. Even though, Ghana has a huge and vastly untapped potential for rice production, there are several constraints that have plagued the rice sector. Notable amongst these constraints are low inherent soil fertility, unfavourable land tenure, poor soil management, poor water management and low mechanization among others. Research has shown that soils of most rice growing environments in Ghana are quite deficient in basic nutrients, the most critical being soil Phosphorus. Majority of rice farmers in Ghana operate on small scale and nutrient additions through fertilization (mineral fertilizers) are quite minimal. For these farmers, varieties that thrive on little available indigenous soil P are necessary. In order to address this problem, JIRCAS in collaboration with Africa Rice and CSIR-Soil Research Institute, have set out to develop low P tolerant rice varieties.

Methodology

An experiment was conducted at Baniekrom in the Ashanti region of Ghana. A split plot design was adopted using fertilizer treatment as main plots and rice variety as sub-plots. Two fertilizer treatments: NPK (60-60-60) kg ha^{-1} and NPK (60-0-60) kg ha^{-1} served as the main plots while 24 selected new rice varieties and 2 local checks constituted the sub-plots. Parameters measured included: germination %, plant vigor, days to flowering, maturity period, above ground biomass and paddy grain yield. The experiment was conducted during the period September-December, 2012.

Results

Preliminary results show that some of the varieties were quite promising. A few varieties (BJ 1, Dawebyan, Santhi-sufaid, TRS 4, Taichung Native 1) including the local checks (Degang & Nabogo) produced similar grain yield under both conditions (P- applied and P not-applied). These varieties produced paddy grain yields of above 4.0 t ha^{-1} (Figure 5). However, the worst performed varieties produced grain yields of less than 2.5 t ha^{-1} and these included Eamata A 16-34, Tox 1011-4-A2, ITA 257 and Nerica 10.

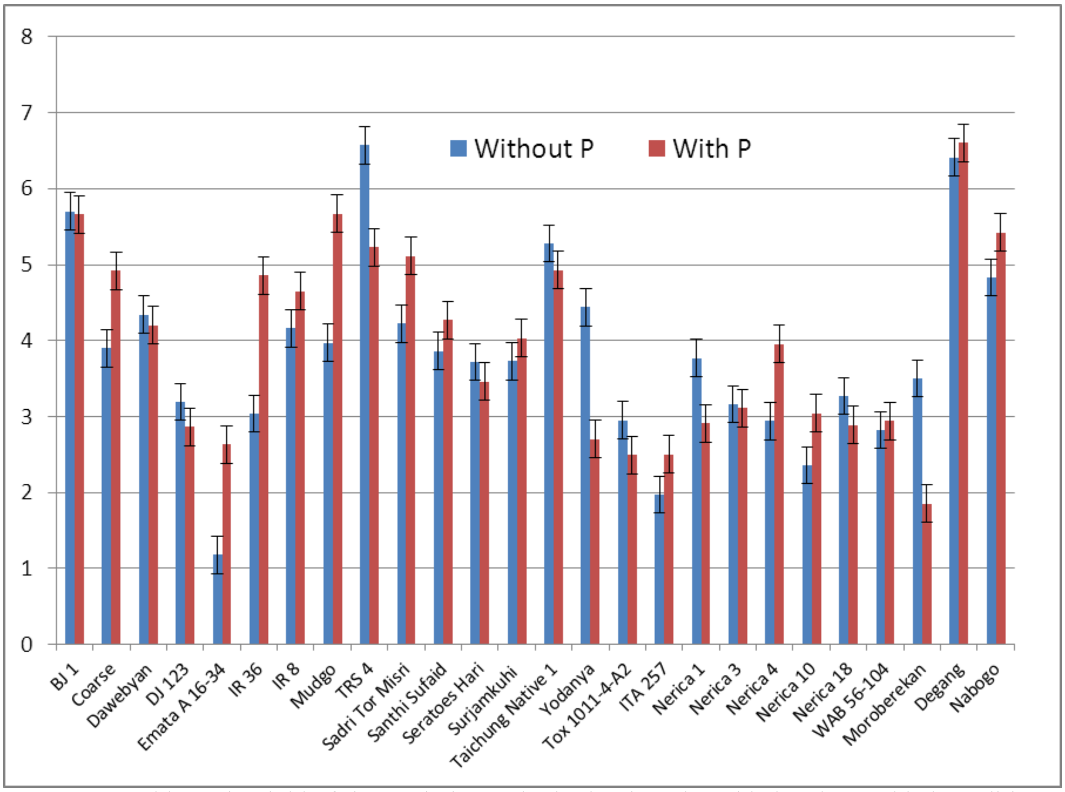

Figure 5. Paddy grain yield of rice varieties under both mineral P added and not added conditions.

The experiment may be repeated during the 2013 growing season based on the availability of funds, for further screening and confirmation of results after which promising lines would be selected for further field testing and evaluation.

2.2.3 Study Title: Residual effect of rice straw and mineral fertilizer on the growth and yield of three rice varieties

Research Team: R.N. Issaka, M.M. Buri and M.A. Essien

Collaborating Institutions: JIRCAS,

Source of Funding: JIRCAS

Duration of Project: 2012

Background

Rice straw is normally burnt or allowed to lie waste in rice fields. Farmers rarely try to incorporate rice straw or its derivatives into their fields. In 2010 a study was conducted to find out the effect of rice straw (in its raw form, composted, ashed or charred) on the performance and grain yield of three rice varieties (Sikamo, Marshall and Jasmine 85). The experiment was repeated in 2011 with only one variety (Sikamo) as the test crop. In 2012, the residual effects of these materials were examined.

Methodology

Only 30 kg/ha N and K_2O were applied (all K and 10 kg N/ha were applied one week after transplanting (WAT), additional 20 kg N/ha was applied at five (5 WAT. The design was a split plot with 3 replications. Rice straw and its derivatives were the main treatments (Table 4). Three rice varieties; Sikamo, Mashall and Jasmine 85 were the sub plot treatments. Two (2) seedlings were transplanted per hill at a spacing of 20 cm x 20 cm.

Table 4. Treatments used in 2010 and 2011

Treatment	Organic material	Mineral fertilizer (kg $N:P_2O_5:K_2O$/ha)
Rice Straw (RS)	4 t ha^{-1}	+ 45-30-30
Compost from RS	2 t ha^{-1}	+ 30-20-20
Char from RS	2 t ha^{-1}	+ 60-20
Ash from RS	2 t ha^{-1}	+ 60-20
Standard	0 t ha^{-1}	+ 90-60-60

Results and discussion

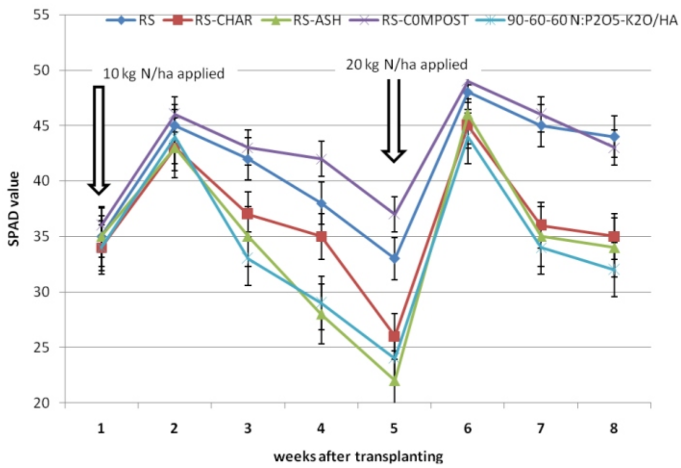

Figure 6. Changes in SPAD value with time

Figure 6 shows changes in SPAD value (related to chlorophyll content) for the various treatments with time. Initially all the plants showed similar SPAD values up to the second week. This may be due to the application of 10 kg N/ha. After the second week SPAD values started declining for all the treatments. The fall in SPAD value was,however,lower where rice straw or rice straw compost were applied. After the 5th week when 20 kg N/ha was applied all the plants gave similar values up to the 6th week with a sharp decline for rice char, rice ash and mineral fertilizer. Gradual release of N from rice straw and rice straw compost may be the main reason why SPAD values were good (> 30%) throughout the experiment.

Table 5. Residual effect of treatments on rice growth and yield.

Treatment	Plant height (cm)	No. of stand/m^2	Number of panicles/plant	No. of panicles/m^2	Stover yield(t/ha)	Grain yield(t/ha)
RS	86a	24.6a	3.2a	237a	6.6ab	5.5ab
RS-CHAR	84a	24.4a	2.9a	209a	6.4b	5.3b
RS-ASH	83a	24.7a	2.8a	186a	6.0b	5.0b
RS-C0MPOST	85a	24.6a	3.4a	218a	7.1a	6.1a
90-60-60 ($N:P_2O_5:K_2O$ ha^{-1})	86a	24.7a	2.8a	186a	6.1b	5.1b

The residual effect of RS-Compost on grain yield was significantly higher than all the treatments except RS (Table 5). RS-Compost and RS decompose relatively slower and therefore release nutrient, especially N, over a longer period compared to Ash and mineral fertilizer (Figure 6). This slow release of nutrients over a longer period partly explains why the residual effect of these materials is relatively better and will play a significant role in soil fertility maintenance.

2.2.4 Study Title: Residual effect of poultry manure on rice growth and yield

Research Team: R.N. Issaka, M.M. Buri and M.A. Essien
Collaborating Institutions: JIRCAS,
Source of Funding: JIRCAS
Duration of Project: 2012

Background

The trial was commenced in 2010 and repeated in 2011. Sole poultry manure, mineral fertilizer and their combinations were used (Table 6). In 2012 the residual effects of these treatments on rice growth and yield was investigated.

Methodology

A Randomized Complete Block Design with 3 replications was used. Sikamo was used as the test crop. Two (2) seedlings were transplanted per hill at 20 x 20 cm. Only 30 kg/ha N and K_2O were applied (all K and 10 kg N/ha were applied one week after transplanting (WAT), additional 20 kg N/ha was applied 5 WAT.

Table 6. Treatment combinations in 2010 and 2011

Treatment	Basal Application (1WAT)	Top Dressing (5 WAT)
6 t ha^{-1} PM (T_1)	_	_
4 t ha^{-1} PM (T_2)	_	_
4 t ha^{-1} PM + 30 kg N/ha (T_3)	_	30 kg N ha^{-1}
2 t ha^{-1} PM + 30 kg N/ha (T_4)	_	30 kg N ha^{-1}
2 t ha^{-1} PM + 0.25 Standard (T_5)	All P&K + 10 kg N ha^{-1}	20 kg N ha^{-1}
Standard (90-60-60 N:P_2O_5:K_2O) (T_6)	All P&K + 30 kg N ha^{-1}	60 kg N ha^{-1}

Results and discussions

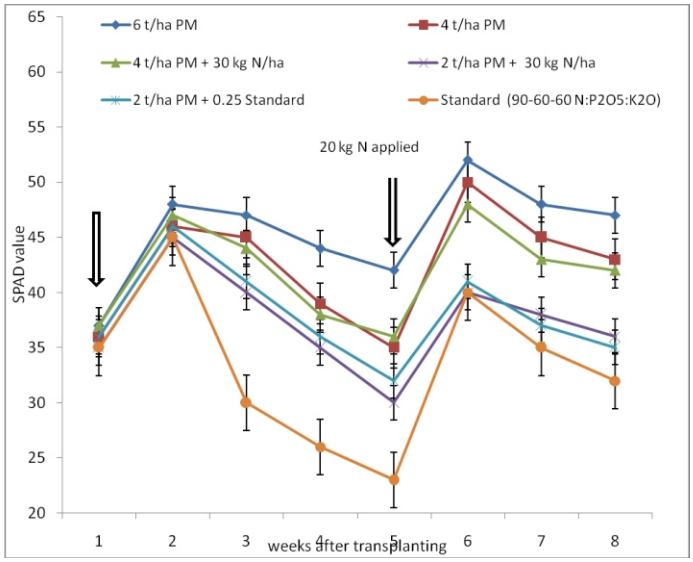

Figure 7. Changes in SPAD values with time

Changes in SPAD value during the growth of the plants are presented in Figure 7. SPAD value shows how green a plants is, an indication of how vigorous the plant is growing. SPAD values were similar in the second week due to application of 10 kg N/ha to all plots. After the second week SPAD values started declining but at different rates. SPAD values fell to the lowest level during the fifth week after which additional 20 kg N/ha was applied to all plots. This raised the SPAD values of plants growing on plots that earlier received 4 or 6 t poultry manure to over 45 in the sixth week. SPAD values again started declining after the sixth week showing similar trend as happened between the second and fifth weeks. Plant growing on plots that received 6 t poultry manure had SPAD values above 40 to the eighth week of growth. This was followed by plants on plots that received 4 t PM ha^{-1} showing values above 35. The residual effect of mineral fertilizer was less effective in maintaining high levels of SPAD values. SPAD values fell to below 25 for plants growing on plots that received only mineral fertilizer (Fig. 7). Gradual release of nutrients, especially nitrogen, by the manure explains the observed trends.

Table 7. Residual effect of treatments on rice yield

Treatment	Plant height (cm)	No. of stand/m^2	Number of panicles/plant	No. of panicles/m^2	Stover yield (t ha^{-1})	Grain yield (t ha^{-1})
6 t ha^{-1} PM	125a	25.0a	3.0a	203a	6.8a	5.8a
4 t ha^{-1} PM	122a	24.3a	3.0a	192ab	6.4ab	5.3ab
4 t ha^{-1} PM + 30 kg N ha^{-1}	121a	24.3a	3.0a	193a	6.7a	5.6a
2 t ha^{-1} PM + 30 kg N ha^{-1}	121a	24.7a	2.7a	192ab	5.8bc	4.6c
2 t ha^{-1} PM + 0.25 Standard	122a	24.7a	2.3a	172ab	5.7bc	4.7bc
Standard (90-60-60 N:P_2O_5:K_2O)	125a	24.0a	2.3a	148b	5.4c	4.4c

The residual effect of poultry manure at 6.0 t ha^{-1}, 4.0 t ha^{-1} and 4.0 t ha^{-1} + 30 kg N ha^{-1} on grain yield was significantly higher than the other treatments (2 t ha^{-1} PM + 0.25 Standard , 2 t ha^{-1} PM + 0.5 Standard). This implies that at 4.0 t ha^{-1} PM and above, optimum grain yield can be obtained. Use of organic fertilizer (poultry manure) show better residual effect than mineral fertilizer. PM is therefore an important source of plant nutrient for effective rice production for poor resource farmers.

2.2.5 Study Title: Effect of Irrigation and Biochar Application on the Growth and Dry Matter Yield of Maize

Research Team: R.N. Issaka, M.M. Buri and A Abunyewa, E Sakyi-Annan

Collaborating Institutions: KNUST,

Duration of Project: 2012

Background

Several studies have shown that biochar amendments can enhance the growth and quality of certain crops. Due to their high surface area, charcoal materials are strong adsorbents of many compounds including water. Biochar is gradually gaining popularity in the country. Thus, a prerequisite to the widescale use of biochar as a soil amendment in agriculture is a thorough assessment of its effects on the soil and plant growth. With the current erratic rainfall, it is proposed that application of biochar at the appropriate rates may enhance water use by plants. This study examines the effect of biochar on plant growth.

Materials and Methods

Study site: The study was conducted in a green house at Soil Research Institute, Kwadaso, Kumasi. The Institute lies on latitude 6° 41'N and longitude 1° 47'W.

Experimental design: Sandy soil (Colluvium material) was collected from the Soil Research Institute, sieved through 3-mm, and adequately homogenized. 5.0 kg of the soil was put into each pot with an inner diameter of 20 cm and a height of 18 cm. The design was a Randomized Complete Block (RCBD) and the pots were arranged in a split plot format with four replications. Water regime (Full irrigation:- the crop was irrigated throughout the trial period and Partial irrigation:- the crop was irrigated for only 3 weeks) were the main treatments and biochar (0, 15, 30, 45 and 60 g/pot) was the sub treatment. The biochar was mixed with soil to a depth of 5 cm in each pot. The biochar was produced from saw dust. Each pot was irrigated with 1.5 L of pipe water and allowed to drain for 2 days. The volumetric water content was measured after the third day. Four seeds of maize (Zea mays L) variety *obatampa* (local name) was planted in each pot. The plants were thinned to 2 per pot after a week and 4 g N-P_2O_5-K_2O (as 15-15-15) applied to each pot. An additional 2 g of Sulphate of Ammonia was applied per pot. Volumetric water content of each pot was measured periodically and 400 mls added when the water content fell below 20%. Number of leaves and plant height were taken weekly.

Stress, as defined by the severity and the number of leaves rolling, was estimated as follows:

- 1:-no stress
- 2:-slight stress, (1-2 leaves showing signs of rolling)
- 3:- stressed, (1 or 2 leaves rolling)
- 4: seriously stressed, (more than 2 but less than 5 leaves rolling)
- 5:-extremely stressed, (whole plant wilting)

The plants were harvested 8 weeks after planting. Fresh and dry matter of plants were measured and recorded.

Results and discussion

Effect of moisture on selected parameters are presented in Table 8. Except for the number of leaves at 5 WAP, plants that were irrigated for 8 weeks were significantly taller, less stressed and gave higher fresh biomass and dry matter. The relative leave water content (RLWC) was also significantly lower under partial irrigation.

Table 8. Effect of irrigation on selected growth parameters

Irrigation	No. of leaves 5 wap	Plant height 5wap (cm)	RLWC (%)	Leaf rolling score 5 WAP	Fresh weight (g/pot)	Dry weight (g/pot)
Full	6.4a	48.5a	83.8a	1.4b	26.6a	6.2a
Partial	6.0a	38.5b	39.1b	4.1a	2.3b	1.7b

The effect of biochar on crop performance varied significantly (Table 9). Plant height and leave rolling scores were similar for all the biochar rates. Number of leaves at 5 WAP was significantly lower for the control than the other treatments which were similar. The relative leave water content (RLWC) showed a significant increasing trend with biochar application. The RLWC was in the order 0 < 15 < 30 = 45 < 60 g/pot. Dry matter was also significantly smaller for the control than all the other treatments. Dry matter obtained for biochar applied at 60 g/plot was significantly higher than 15 g/plot and 30 g/plot but similar to 45 g/plot. The ability of biochar in making moisture more available may partly explain the observed trend.

Table 9. Effect of biochar on selected growth parameters

Biochar (g/pot)	No. of leaves 5 WAP	Plant height 5WAP (cm)	RLWC (%)	Leaf rolling score 5 WAP	Fresh weight (g/pot)	Dry weight (g/pot)
0	5.6b	42.8a	51.9d	3.0a	12.2b	3.3c
15	6.2a	45.1a	58.2c	2.6a	12.7b	3.8b
30	6.4a	42.1a	62.8b	2.4a	15.4a	3.9b
45	6.2a	42.7a	64.5b	2.9a	15.8a	4.2ab
60	6.5a	44.8a	69.9a	2.6a	16.3a	4.5a

2.2.6 Study Title: Determining Organic and Inorganic Fertilization rates for Increased Plantain production in Ghana.

Research Team: J. Oppong and P. Mintah

Collaborating Institutions: CSIR-CRI

Duration of Project: 2012

Introduction

Plantain (*Musa* spp. AAB) is a starchy staple crop of considerable importance in Ghana. It contributes about 13.1 % of the Agricultural Gross Domestic Product (MOFA-SRID, 2006). Local consumption of plantain constitutes about 90 % of production in Ghana. So the crop is ranked high in the country's food preference (Schill *et al*., 1996). Plantain also serves as an important source of family income due to its high price compared with other starchy staples. However, its production is constrained by poor soil fertility and dry season soil moisture deficit which rank very high among other problems. These two constraints lower the yield of both landraces and improved varieties, and reduce the quality of planting material significantly.

Though various approaches of soil nutrient and water management with inorganic and organic fertilization are being practiced in Ghana, no standard fertilization regime has been recommended to plantain farmers. However, both inorganic and organic fertilizers are known to increase plantain yield due to their positive impact on soil nutrients and moisture storage. Locally, available organic materials that are known to be of fertilizer value such as poultry manure and cocoa pod husk are often used by farmers to boost plantain yield. To be able to obtain the appropriate inorganic and organic fertilization rates for plantain production in Ghana a study was done in two phases with the following objectives.

1. To determine the relationship between soil nutrient level and leaf nutrient content as well as bunch yield
2. To determine the fertilizer rates needed for different soils and conduct a response study for the rates.

Materials and Methods.

Phase 1: Relating soil fertility status to crop yield to determine fertilizer rates.

This study was conducted in Ashanti and Brong Ahafo regions at six locations (three in each region). It involved soil and leaf sampling and bunch weights measurement. The soils and the leaf samples were analyzed using standard laboratory procedures. The mean values from soils and leaves analysis and plantain yields were subjected to statistical analysis.

Results

Results so far obtained show that plantain bunch yields ranged from 3.0 to 10 ton ha^{-1} in the study area. There is a very strong correlation between soil organic matter, NPK levels, and bunch yield. However there is no such correlation between leaf nutrients and bunch yield. The mean values of soil chemical properties and bunch yield is presented.

Table 10: Mean values of soil chemical properties and bunch yield

Property	Ashanti region	Brong Ahafo region
Org Carbon (%)	1.69	2.48
Total Nitrogen (%)	0.14	0.23
C/N	12.1	10.8
AV, P (Bray 2) mg kg^{-1}	11.9	16.9
pH (H_20) 1:2,5	6.5	7.1
Ex. Na^+ (cmol kg^{-1})	0.04	0.06
Ex. K^+ (cmol kg^{-1})	0.3	0.4
Ex. Mg^{2+} (cmol kg^{-1})	2.5	2.9
Ca^{2+} (cmol kg^{-1})	1.6	1.8
Al + H (cmol kg^{-1})	0.3	0.3
ECEC (cmol kg^{-1})	4.5	5.1
Mean bunch yield tons ha^{-1}	5.4	7.7

Table 11: Range of location soil chemical properties and bunch yield

Region	Ashanti Region			Brong Ahafo Region		
Soil Properties/Location	Mpobi	M'teng	Adwum.	Kenyasi	Adomako	K'dua
Org Carbon (%)	1.4 -2.5	1.8 - 2.07	1.2 - 2.8	2.2- 3.0	2.5 - 3.6	2.4 -3.3
Total Nitrogen (%)	0.1 -.25	0.13 - 0.2	0.1 - 0.26	0.1 - 0.2	0.2 - 0.28	0.2 -0.27
Av. P (Bray 2) mg kg^{-1}	4.9 - 18.	5.4 - 17.0	7.5 - 20.	11.8 -24	20.1 -22	13 - 22
pH (H_20) 1:2.5	6.6	6.8	6.7	6.9	7.2	7.1
K+ (cmol kg)	0.2 - 0.5	0.3	0.3	0.2 - 0.5	0.3	0.3
Bunch yield tons ha	3.5 - 7.5	4.5 - 7.6	3.3 - 6.8	5.4 - 9.8	5.5 - 10.2	6. - 10.1

Comments:

The study is on-going.

References.

Ministry of Food and Agriculture-Statistical Research and Information Directorate, 2006 Agriculture in Ghana, Facts and Figures 53pp.

Schill, P. Gold, C.S. and Afreh-Namah, K. 1996 Assessment and characterization of constraints in plantain production in Ghana as an example for West Africa.

2.2.7 Study Title: **CSIR Yam fertilizer response to NPK fertilizer on some benchmark soils in the interior savanna zone of Ghana: calibrating the QUEFTS models for yam fertilization in Ghana**

Research Team: F.M. Tetteh, G. Quansah and S. Ofosu Frempong

Collaborating Institutions: CSIR-CRI, MoFA

Source of Funding: WAAPP

Introduction

Yam is important for food security in Ghana. Despite its importance, yam cultivation has been declining. Currently the increase in yam production has resulted mostly from increase in land-area under cultivation while the yields per unit area continue to decline. The increased demand for yam by consumers can only be met by an increase in yam productivity.

The advantage of the Quantitative Evaluation of the Fertility of Tropical Soils (QUEFTS) model is that a targeted economic yield of yam will be obtained based on the initial fertility status of the land. The usage of the QUEFTS model (Janssen *et al*., 1990), a decision support tool developed for the quantitative evaluation of initial fertility of tropical soils, will assist to meet this objective. This will involve the determination of nutrient-use efficiency and the recovery rate of yam, the determination of the economic (marketable) yield and the total amount of nutrients absorbed by the crop and the estimation of the amount of nutrients needed to attain a given yield (targeted yield). It defines dilution limits and levels of accumulation of a given nutrient in the plant, which varies from one crop to another.

Goal and Objectives

The goal of this study is to adapt the QUEFTS model for yam fertilization in Ghana.

The specific objectives are:

- To evaluate the performances of the original QUEFTS model for yam fertilization;
- To establish optimum and economic fertilizer rates for yam grown on benchmark soils.

Materials and methods

The on-station experiments were carried out at **Wenchi** and **Atebubu** in the Brong-Ahafo Region on a *Damongo* and *Lima* soil series respectively (Benchmark soils). White yam (variety: '*Puna*'), which is widely grown in Ghana was used. Mineral Fertilizers used were Urea (45% N), TSP (46% P_2O_5) and KCl (60% K_2O). The trial treatments were determined in a way to express the dilution limits and the accumulation of the nutrients and the capacity of the soil to furnish the major nutrients according to the increasing rates of the nutrients (elements). Altogether there were 10 treatments (Table 12). All cropping practices such as planting, weeding, fertilizer applications, etc. were done on the same days on all the respective plots.

Table 12. Yam Fertilization Trial Treatment

Treatments	Rates (kg ha^{-1}) N	P_2O_5	K_2O
T0	0	0	0
T1	0	40	130
T2	40	40	130
T3	80	0	130
T4	80	20	130
T5	80	40	0
T6	80	40	65
T7	80	40	130
T8	40	20	65
T9	100	50	170

Data Collection

Composite soil samples were taken at each site before setting up the trials. These samples were taken from 3 layers (horizons): 0-20cm, 20-40cm and >40cm for chemical analyses. The parameters to analyzed include organic carbon content, total nitrogen, available phosphorus, exchangeable potassium, CEC, pH and the physical properties (clay, silt, sand content). A series of measurements were done throughout the trial on a number of tagged plants (4 stands / plot). These were: Date of germination of yam (75% sprouting); Plant height at 2 months intervals, and leaf area index (LAI) at the time of measuring the plant height.

The daily climatic data of minimum and maximum temperatures, of solar radiations and of rainfall were also collected at Wenchi and Atebubu.

Statistical Analysis

The data were subjected to analysis of variance (ANOVA) using the statistical software STATISTICA and the mean comparison was done by the statistical software Statsview. In addition, the following tools were used to evaluate the performance of the QUEFTS model:

Line 1:1 coupled with the coefficient of correlation; the acceptable precision envelope method (Mitchell, 1997); the normalized root mean square error NRMSE (Du Toit *et al*., 2001), the mean square deviation (MSD) and its components (Kobayashi and Us Salam, 2000) and the Wilmott index of agreement (Willmott, 1981).

Results

Tables 13 Yeild of yam tubers fresh and dry matter weight at Atebubu

Treatment Mean Tuber Yield kg/ha - Atebubu			
	Fresh wt.	**Conversion factor**	**Dry wt.**
T_0	13687.5	0.3314	4536.04
T_1	20593.75	0.312125	6427.82
T_2	22906.25	0.299175	6852.98
T_3	18331.25	0.288	5279.4
T_4	19062.5	0.3212	6122.88
T_5	18343.75	0.30815	5652.63
T_6	13312.5	0.296425	3946.16
T_7	20156.25	0.311925	6287.24
T_8	13843.75	0.308225	4266.99
T_9	17718.75	0.303225	5372.77

Table 14: Yield of yam tubers (fresh and dry matter weight) at Wenchi.

Treatment	Mean Tuber Yield kg/ha – Wenchi		
	Fresh wt.	**Conversion factor**	**Dry wt.**
T_0	14063	0.3428	4820.8
T_1	12375	0.3072	3801.6
T_2	14687.5	0.3073	4513.47
T_3	14843.75	0.337025	5002.71
T_4	11875	0.327375	3887.58
T_5	13437.5	0.264675	3556.57
T_6	18125	0.328525	5954.52
T_7	12187.5	0.334525	4077.02
T_8	12250	0.30185	3697.66
T_9	13125	0.294925	3870.89

Table 15: Physiological Use Efficiencies of nutrient uptake by yam at Wenchi and Atebubu

	Physiological Use Internal Efficiencies					
	Wenchi			Atebubu		
	N	P	K	N	P	K
2.5 Percentile	27.8	368.3	88.6	25.9	394.4	100.6
97.5 Percentile	33.4	573.0	163.4	34.9	734.4	204.5
Mean	30.6	470.6	126.0	30.4	564.4	152.5

Table 16: Indigenous soil nutrient supply at Wenchi and Atebubu

	Soil Nutrient Supply (kg/ha)	
Limiting Nutrient	Wenchi	Atebubu
0 – 40 – 130 (N)	136.9	188.2
80 – 0 – 130 (P)	9.3	11.3
80 – 40 – 0 (K)	36.1	27.5

Table 17. The most limiting nutrients in soils at Wenchi and Atebubu

Treatment	Wenchi	Atebubu
0 – 0 – 0	14063	13687.5
0 – 40 – 130	12375.0(-)	20593.8
80 – 0 – 130	14843.8	18331.3
80 – 40 – 0	13437.5	18343.8
Limiting Nutrient	N	P&K

Table 15 shows the physiological use efficiency values obtained for yam at Wenchi and Atebubu. The 5 and 95% percentile values were obtained as borderlines (Fig. 8 & 9) The measured PhE showed that the uptake of 1 kg N produces on average 30.6 kg yam DM, corresponding to a reciprocal physiological efficiency (R-PhE) of 32.7 kg N required to produce 1Mg yam DM at Wenchi. Likewise, the uptake of 1 kg P produces 470.6 kg yam DM, corresponding to 2.1 kg P to produce 1 Mg yam DM. With 1 kg K taken up, it produced 126 kg yam DM, corresponding to 7.9 kg K for the production of 1Mg yam DM at Wenchi.

Estimation of balanced nutrition is based on the following equations:

1. B-PhEx = (aPhEx-bPhEx)/2
2. B-Tyx = PhEx*Ux
3. UN/UP=B-PhEP/B-PhEN

where B-PhE = physiological nutrient use efficiency (PhE) for balanced nutrition (B), x = specific nutrient (N, P or K), a = accumulation, d = dilution, B-TY = Targeted yield at balanced nutrition, U = nutrient uptake to attain B-TY

Table 16 shows that the indigenous soil N and P supply values were higher in Atebubu than in Wenchi. Wenchi soils are therefore poorer in N and P. Table 17 shows the most limiting nutrients at the Wenchi and Atebubu sites.

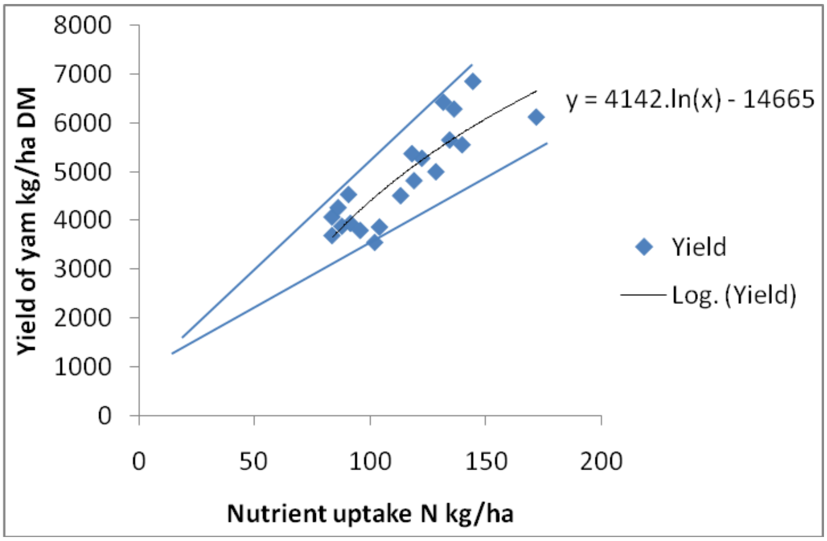

Figure 8: Physiological use efficiency of N for yam at Wenchi. (max. accumulation and max. dilution)

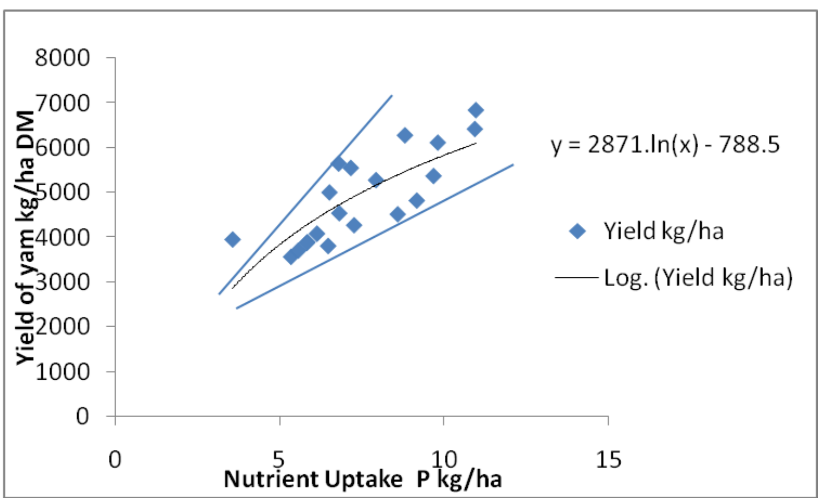

Figure 9: Physiological use efficiency of P for yam at Atebubu (maximum dilution and maximum accumulation)

Fertilizer recommendation

QUEFTS allows for the determination of the optimum quantity of fertilizer for a particular soil type and input and output prices, with a limited budget. This means that fertilizer recommendations can be developed for various yield targets depending on the economic situation of the farmer, i.e. small scale resource poor, medium scale and large scale farmers (Tables 19 and 20)

Table 18: Fertilizer recommendation for the Atebubu site

Targeted Yield	N	P	K
9 t DMW	112.6	5.2	35.1
8 t DMW	79.8	3.4	28.3
7 t DMW	46.9	1.6	21.6
6 t DMW	12.4	0	15.0

Table 19: Fertilizer recommendation for the Wenchi site

Targeted Yield	N	P	K
7 t DMW	107.9	5.9	22.5
6 t DMW	73.6	3.8	14.4
5 t DMW	39.4	1.7	6.3

Conclusion

Calibrating the QUEFTS' model for yam to determine fertilizer recommendations for targeted yam yields and most yield limiting nutrients led to promising results. Further research will be conducted on other benchmark soils and results validated on farmers' fields

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2.2.8 Study Title: **Modeling site specific maize fertilizer recommendation in Sudan Savanna agro-ecology of Ghana**

SRI Research Team: F.M. Tetteh, G.W. Quansah, S. Ofosu Frempong,
Lead Institutions: CSIR-SARI,
Source of Funding: AGRA
Duration of Project: 2010-2014

Background

The introduction of high yielding varieties alone has not solved the problem of low yields and sustainable increase in maize production. The use of old or blanket fertilizer recommendation in the Sudan savanna agro-ecological zone is not useful in recent times. Inorganic fertilizer use is the core strategy to overcome soil fertility depletion through nutrient mining and soil degradation.

There is also inadequate knowledge and inherent complexities about how the weather, soil and crop interact to affect crop production. Many researchers are recently using models. The use of models also helps in matching biological requirement of crops for achieving specified objectives faster than the traditional method which requires many years. Decision Support Systems for Agro-technology Transfer (DSSAT) model has been used and is able to approximate weather, soil and crop dynamics for a narrow range of factors that influence weather, soil and crop growth under limited conditions (Hoogenboom *et al*., 2004, 2009). The general objective of the study was to refine profitable fertilizer recommendation for maize on selected benchmark soils of the Sudan savanna agro-ecological zone of Ghana.

Materials and methods

Study area

The study was carried out in the Sudan savanna agro-ecological zone at the extreme north-east corner of Ghana. The area lies roughly between 10° 30' and 11" North latitude of the equator and 0° and 1' 30" West longitude of the zero meridian and covers an area of 1765 km^2 along Ghana-Burkina Faso border. The mean annual rainfall is 1365 mm but the highest amount is recorded in August (Nyarko *et al*., 2008). The mean monthly minimum temperature ranges from 18.9 to 25.7 °C and the mean monthly maximum temperature also ranges from 32.4 to 38.6 °C. The mean annual minimum and maximum temperatures are 22.3 and 34.3 °C, respectively (Adu, 1969). The dominant soil in the study area was

Tanchera series (Ferric Lixisol, FAO, 2006).

Field experiment and simulation study

A field experiment was conducted for 2 years during the rainy seasons of 2010 and 2011. A randomized complete block design with 4 replications and a plot size of 6.0 m x 4.8 m was used. The treatments used in the experiments were: 0-0-0, 0-90-90, 40-90-90, 80-90-90, 120-0-90, 120-45-90, 120-90-90, 120-90-0, 120-90-45 and 160-90-90 kg ha^{-1} N-P_2O_5-K_2O respectively. The maize variety used was *obaatanpa* and was planted at a spacing of 80 cm x 40 cm.

The source of N was urea, P was from triple super phosphate and K was obtained from muriate of potash. The soil file includes the analytical characteristics of the soil of the study field such as particle size, pH, nitrate, ammonium, total N, available phosphorus, exchangeable potassium, organic carbon, bulk density, and volumetric moisture content. The weather file also consists of precipitation, minimum and maximum temperatures and solar radiation of the study field from 1960 to 2050. Field results were used to calibrate the genetic co-efficient of maize. These model inputs were integrated to provide a framework for simulating and analyzing outputs.

Results and discussion

Model calibration and validation

The values for the thermal time from seedling emergence to the end of juvenile phase (P1 in degree days), photoperiod sensitivity coefficient (P2 in days), thermal time from silking to time of physiological maturity (P5 in degree days), maximum kernel number per plant (G2), potential grain filling rate (G3 in mgd^{-1}) and thermal time between successive leaf tip appearance (PHINT in degree days) were 380, 0.1, 750, 532, 8, 38.9 for 2010 growing season and 300, 0.1, 700, 693, 7.8, 56.8 for 2011 growing season respectively.

The CSM-CERES model was validated by comparing the observed field data with the simulated data for 2010 and 2011 growing seasons. The corresponding results were as follows:

Maturity (grain yield)

The model simulation of grain yield was in similar trend as the observed field results for the 2010 and 2011 growing season respectively. The mean difference between the observed and simulated grain yield was significant for 2010 and not significant for 2011 using t-test for paired plot analysis. The R-square value between the observed and the simulated result was 0.92 for 2010 season and 0.89 for 2011 season (Table1). The normalized root mean square error (NRMSE) between the observed and the simulated grain yield results for 2010 and 2011were 26.13 % and 18.24 % respectively. This also confirms that the model performance in simulating the yield at maturity was in acceptable range for 2010 season and good range for 2011 season (Jamieson *et al*., 1991; Loague and Green, 1991).

Seasonal analysis

The yields at maturity for the treatments for 2010 and 2011 growing seasons were used to run 90 years seasonal analysis and discussed under the following:

Biophysical analysis

The biophysical analysis determined the minimum and maximum yields for the treatments during the 90 years. Treatment 10 (160-90-90) gave the best yield among the treatments but was not significantly different from treatment 8 (120-90-0), 5 (120-0-90), 9 (120-90-45), 7 (120-90-90) and 6 (120-45-90) during the 90 years seasonal analysis using 2010 growing season grain yield result. Its minimum yield up to the 25 % yield was above 2200 kg ha^{-1} which was above 75 % yield of the rest of the treatments (Figure 10). It had a maximum yield of above 3800 kg ha^{-1}. Treatment 2 (0-90-90) had the least yield with a minimum of 640 kg ha^{-1} and maximum yield of 1400 kg ha^{-1}. This showed the level of significance of N in the development and growth of maize. Cumulative probability of grain yield for using treatment 10 was high within 25 to 75 % level (about 2550 to 3350 kg ha^{-1}) compared to the rest of the treatments which were within 75 to 100% level (Figure 1). This was due to a wide range of yield obtained by 25 to 75 % level of treatment 10. Treatment 7 (120-90-90) together with treatments 5 (120-0-90), 6 (120-45-90) and 9 (120-90-45) gave the highest yield but were not significantly different from treatment 10 (160-90-90), 4 (80-90-90) and 8 (120-90-0) for the 90 years seasonal analysis using 2011 growing season grain yield result .

Economic and strategic analysis

Mean-Gini Dominance analysis was performed to evaluate the economic strategies of the treatments for 50 years behind and 40 years ahead. The result showed that treatment 160-90-90 and 120-0-90 were the best fertilizer recommendations for economic strategic production of maize in the Sudan savanna agro-ecological zone of Ghana in 2010 and 2011 growing seasons respectively (Table 21).

Conclusion

Maize grain yield was affected by different rates of fertilizers. Treatments 160-90-90 and 120-0-90 had the highest grain yield for the 2010 and 2011 growing seasons respectively. The model predictions were generally very good and were in the same trend as the observed field results. This suggests that the model can be used as a tool for developing site specific fertilizer recommendation for improved maize and other crops production in the country.

Recommendation

Treatment 120-90-90 was the best due to types of fertilizer combinations available in the Ghanaian market. Testing of CSM-CERES-Maize model in DSSAT and its application in this study confirmed that, the model can be used as a research tool in various agro-ecological environment of the country for site specific fertilizer recommendation.

Table 20: Comparison between observed and simulated maize yield results at Navrongo, Ghana.

	2010 YIELD PARAMETER (kg/ha)			2011 YIELD PARAMETER (kg/ha)		
	Grain	Stover	Total biomass	Grain	Stover	Total biomass
[a]Obs	1940	7635	10487	2385	5250	7638
[b]Sim	2280	9075	11268	2622	6351	8926
[c]MD	340*	1440**	781**	236NS	1101**	1289**
[d]RMSE	507.02	1622.41	855.17	435.09	1471.41	1696.05
[e]R-Sqaure	0.92	0.89	0.99	0.89	0.75	0.85
[f]NRMSE (%)	26.13	21.25	08.15	18.24	28.03	22.21

[a]Observed; [b]Simulted; [c]Mean Difference; [d]Root Mean Square Error; [e]Root Square; [f]Normalised Root Mean Square Error; NS= Not significant; *= Significant and **= Highly significant.

Table 21: Ninety years (1960-2050) Mean-Gini dominance analysis of seasonal analysis for different rates of NPK fertilizer at Navrongo, Ghana.

	2010			2011		
Treatment	E(x) (€)	E(x)-F(x) (€)	Efficiency	E(x) (€)	E(x)-F(x) (€)	Efficiency
0-0-0	15.2	-1.3	NO	-22.1	-3.4	NO
0-90-90	14.7	-1.4	NO	-83.9	-95.8	NO
40-90-90	27.2	8.6	NO	38.4	13.1	NO
80-90-90	69.8	45.9	NO	196.3	154.3	NO
120-0-90	146.6	111.4	NO	247.0	191.3	YES
120-45-90	137.0	103.8	NO	235.4	179.7	NO
120-90-90	137.0	103.7	NO	225.5	169.9	NO
120-90-0	154.3	116.7	NO	227.3	173.7	NO
120-90-45	137.5	104.3	NO	227.5	169.0	NO
160-90-90	236.6	190.7	YES	181.8	127.3	NO

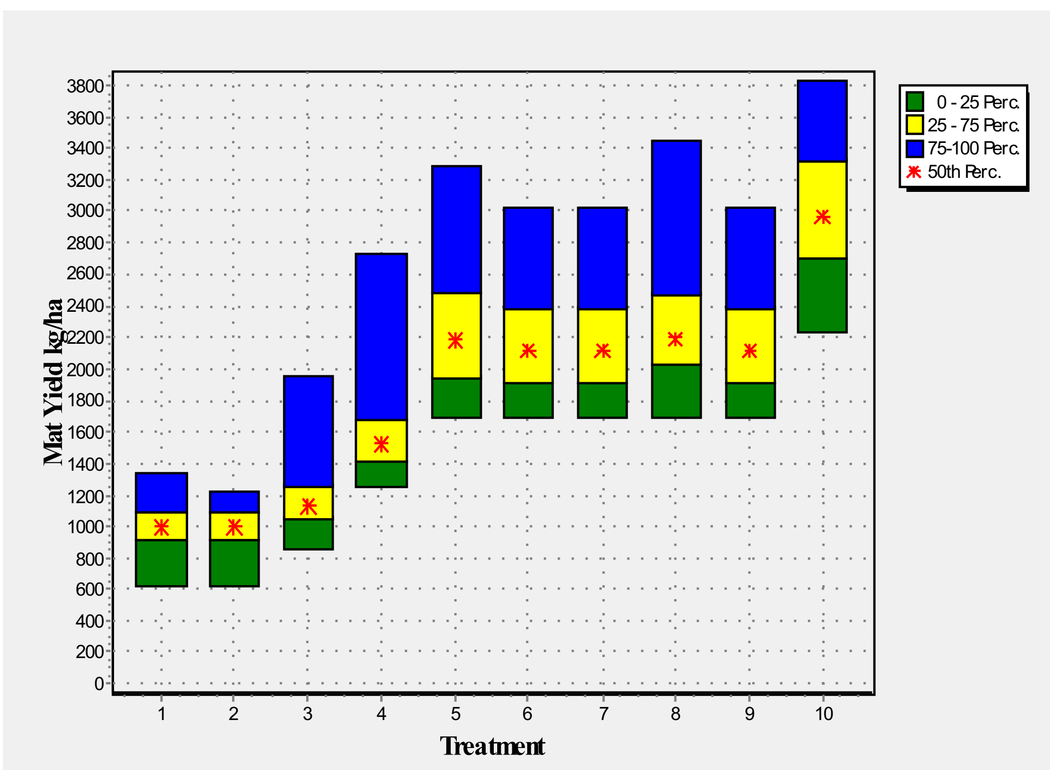

Figure 6: Maize yield as affected by different rates of NPK fertilizer for 90 years (1960-2050) biophysical analysis of seasonal analysis using 2010 growing season grian yield result at Navrongo; 1 = 0-0-0; 2 = 0-90-90; 3 = 40-90-90; 4 = 80-90-90; 5 =120-0-90; 6 = 120-45-90; 7 = 120-90-90; 8 = 120-90-0; 9 = 120-90-45; 10 = 160-90-90 NPK kg/ha respectively.

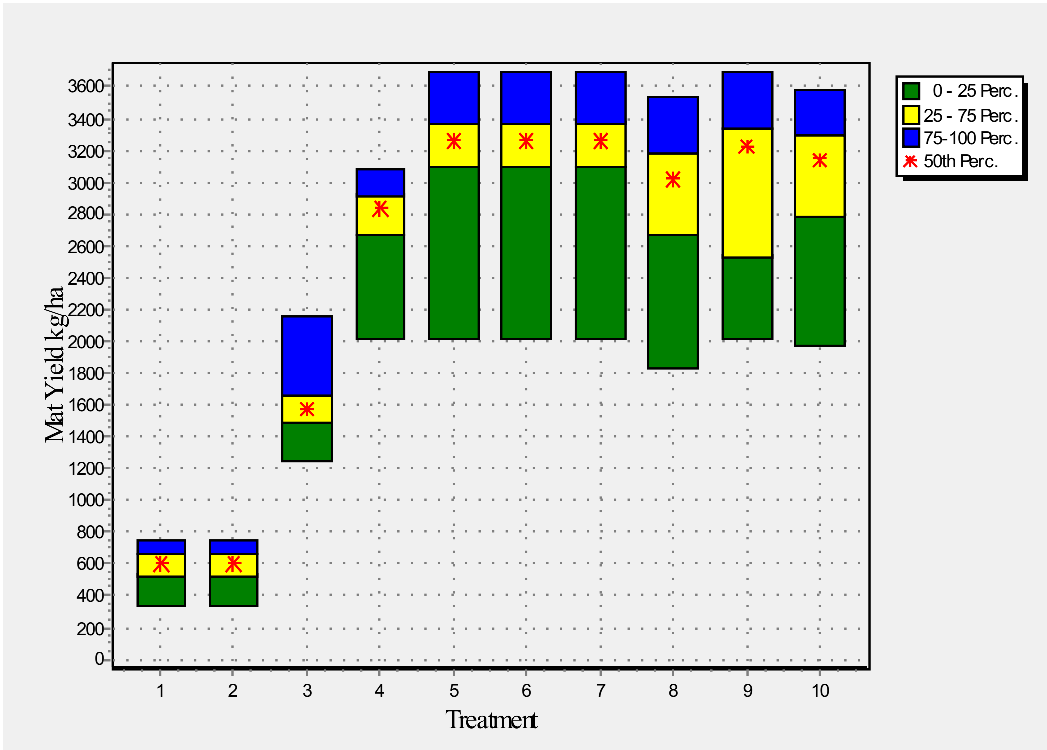

Figure 11: Maize yield as affected by different rates of NPK fertilizer for 90 years (1960-2050) biophysical analysis of seasonal analysis using 2012 growing season grain yield result at Navrongo. 1 = 0-0-0; 2 = 0-90-90; 3 = 40-90-90; 4 = 80-90-90; 5 =120-0-90; 6 = 120-45-90; 7 = 120-90-90; 8 = 120-90-0; 9 = 120-90-45; 10 = 160-90-90 NPK kg/ha respectively.

2.2.9 Study Title: **Effects of Biochar and Maize Stover Mulch on the Physical Properties of a Sandy Loam Soil and Maize Yield**

SRI Research Team: E. Dugan,

Collaborating Institutions: University of Reading and University of Edinburg, UK

Duration of Project: 2009-2012

Introduction

The use of charred biomass, which is popularly referred to as biochar, as a soil amendment has been suggested as a way to improve soils productivity by improving the physical, biological and chemical properties of the soil (Sohi *et al.,* 2010). Most studies have focused on the modifications to the soils' chemical and biological properties, but limited quantitative studies exist on modification to the soils' physical properties. Moreover, any benefit that could otherwise have been obtained from the uncharred biomass when used as soil amendment is hardly compared in studies to make an informed choice between the charred and un-charred biomass (biochar). We had hypothesized prior to starting of this study that biochar, including charcoal, would improve yields of crops by improving the soil physical environment. The physical environment refers to attributes of soil physical conditions that affect crop performance, as opposed to those achieved through chemical or biological means. We had also hypothesized that charred maize stover would give a better nutrient and environmental management option than the raw maize stover used as stubble mulch.

Methodology

Field application of locally manufactured charcoal, maize stover biochar and maize stover mulch were conducted on a sandy loam soil (Chromic Lixisol – WRB, 1998). Prior to planting, soil samples were taken at 0-15cm depth, for laboratory analysis to know the nutrient status of the soil and to provide a guideline in calculating fertilizer application rates required. The fertilizers were applied at the rate of 60 kg ha^{-1}N, P_2O_5, and K_2O, to ensure that none of the major nutrients was found limiting. The maize stover biochar was prepared at 420 ^oC using muffle furnace; and at a low heating rate of 0.1 ^oC/second from ambient temperature. The experimental design was a randomized complete block design (RCBD) and replicated three times. The treatments were: a) 5 t ha^{-1} maize stover biochar; b) 14.6 t ha^{-1} dried uncharred maize stover mulch (stubble); c) 5 t ha^{-1} charcoal and d) a control plot, which had none of the above treatments. Each plot size measured 7.2 m^2 (3 m x 2.4 m), and a distance of 2 m was left between plots of adjacent blocks. Mounted on an automatic weather station (AWS), a DL2e data logger from Delta-T Devices Ltd. was used to automatically record and store soil moisture, temperature and surface temperature data (half-hourly averages of 30 seconds) from sensors. Three analogue cards were installed giving a total of 36 differential channels to which 12 ThetaProbes– type ML2x (T_p = 12), 12 thermistors (T_m = 12), and 12 thermocouples (T_c = 12) were connected for the soil moisture, temperature and surface temperatures respectively. One of the 12 T_p,T_m and T_c was allotted to each of four treatments in triplicates,for the 12-plot experimental layout. The T_c and T_m were installed at 2 cm and 10 cm respectively below the soil, whereas the $T_p$was installed at 10 cm depth below the soil.The data logger was placed in a metal box to prevent damage by rainfall, and direct exposure to solar radiation. The stored data were downloaded by serial interface (RS 232) via a laptop for analysis.The output of the T_p was in millivolts (V), which were later converted to a volumetric soil moisture unit (θ_v %) using the formula:

$$\theta_v = \frac{(1.07 + 6.4V - 6.4V^2 + 4.7V^3) - 1.6}{8.4} \quad (1)$$

In addition, a hand-held ThetaProbe connected to a Delta-T moisture meter HH2 was occasionally used to take instantaneous moisture readings (at four different spots per plot) by pushing the probe into the soil until the rods were fully inserted. The volumetric moisture status (θ_v %) was read off the moisture meter and recorded. Four measurements from locations that were close together were taken in order to cater for the small scale variability in transpiration and evaporation losses, soil composition, density etc. However, the assumption was that the soil on each plot was homogeneous irrespective of the treatment. Before using the parametric statistical tests ANOVA fromGenStat™ statistical software, 13th edition, data sets were tested for normality. All data were normally distributed.

Results

The following results were obtained:

1. Higher moisture content in the maize stover mulch amended plot (UNMS) was observed. This was followed by charcoal (CH) plots as compared to the charred maize stover (CHMS) and control (CTR) plots – Figure 12(a);
2. UNMS amended plots were warmer at nights, but cooler during the day. On the contrary, CTR plots were cooler at nights but warmer during the day, but biochar(CH and CHMS) plots were warmer at night and cooler during the day compared to CTR – Figure 12(b);
3. Maize yield were higher in UNMS amended plots compared to others. This was followed by CH, then CHMS and CTR in that order – Table 22;
4. UNMS presents a better option in terms of growth, development and yield of maize. However, given the readily decomposition of the uncharred maize stover releasing CO_2 into the atmosphere, CHMS could present a better option in terms of carbon capture and storage in the soil compared to the UNMS.

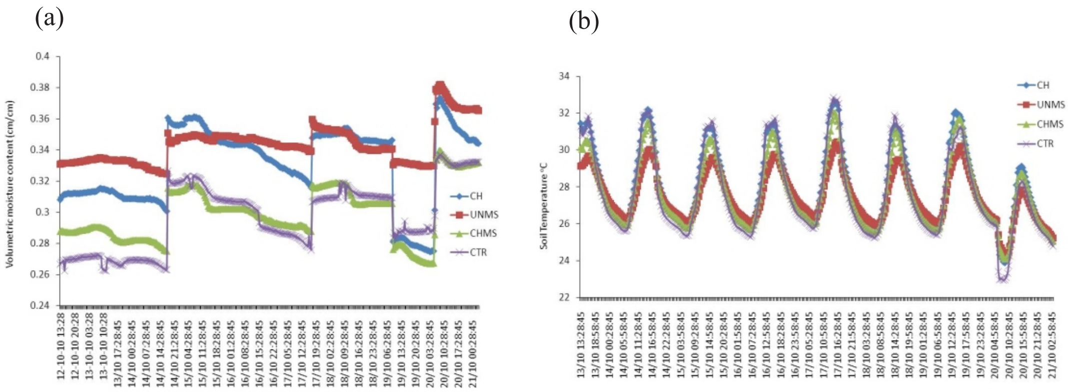

Figure 12(a) & (b): Variation of soil moisture and temperature of biochar, maize stover mulch amended and control plots. CH = Charcoal; CHMS = Charred maize stover; UNMS; = Uncharred maize stover; CTR = Control soil

Table 22: Mean yield parameters of maize and Duncan's multiple comparisons of the means

Treatment	Yield (tha^{-1})			
	stover	Cob	De-husked cob	Grain yield
CTR	4.28(a)	7.16(a)	5.56(a)	4.43(a)
CHMS	4.44(a)	7.82(b)	5.72(a)	4.71(b)
CH	4.79(ab)	9.05 (c)	5.94(b)	4.93 (c)
UNMS	5.29(b)	9.61 (c)	6.38 (c)	5.22(d)

2.2.10 Study Title: **Improved tree fallow: an integrated nutrient management (INM) option for improving maize yield on smallholder farms with in-situ biomass**

SRI Research Team: E. Gaisie and G. Quansah

Duration of Project: 2012

Introduction

Fallow vegetation plays an important role in maintaining and restoring soil productivity in Ghana. The traditional approach to soil fertility restoration is through the spontaneous regeneration of vegetation which is seriously under pressure due to the expansion of cropland (Amissah-Arthur *et al., 2000).* There is therefore the need to intervene the fallow period with fast growing nitrogen fixing trees (FGNFT) to overcome the decline in soil fertility on smallholder farms and restore crop yields to appreciable levels.

Several studies have reported high crop response to application of organic materials from agroforestry trees (Kang et al., 1999, Makumba et al., 2006), high synergies between organic fertilizer and inorganic fertilizer (Kwesiga, 2001; Makumba et al., 2006) with resultant rise in household incomes.

Smallholder farmers are therefore challenged with the sustainability of their crop production and maintenance of soil fertility due to inadequate fertilizer usage on farmer's fields and also the lack of money to purchase enough fertilizer even at subsidized cost.

The objective of the study was to address the deficit in nutrient application by the inadequate use of inorganic fertilizer and improve soil fertility on smallholder farms and raise yields.

Methodology

A study was conducted at Kwadaso to investigate the effect of the two tree species on maize yields. Six (6) treatments were applied in a Completely Randomized Design with three (3) replicates. The treatments were: T1 = Control, T2 = NPK 120-60-60, T3 = *Gliricidia sepium* (4t/ha), T4 = *Moringa oleifera* (4t/ha), T5 = *Gliricidia sepium* (2t/ha) + NPK 60-30-30 and T6 = *Moringa oleifera* (2t/ha) + NPK 60-30-30. Maize variety Obatampa was used in the experiment. Land preparation was done by the application of herbicides. Data collected were subjected to analysis of variance (ANOVA).

Results and discussion

Initial results from harvested maize showed very promising trends as reported in Table 23 below;

Table 23. Maize yields under planted fallows

Treatment	Yields (t/ha)
T1. Control	2.34b
T2. NPK 120 -60 -60	3.48a
T3. *Gliricidia sepium* (4t/ha)	3.54a
T4. *Moringa oleifera* (4t/ha)	3.37a
T5. *Gliricidia sepium* (2t/ha) + NPK 60 -30 -30	4.27a
T6. Moringa oleifera (2t/ha) + NPK 60 -30 -30	3.46a
SE	1.78

Means in the same column followed by the same letter are not significantly different from each other ($P \leq 0.05$)

From the results maize yield in the major season were in the order *Gliricidia sepium* (2t/ha) + NPK 60-30-30 = *Gliricidia sepium* (4t/ha) = NPK 120-60-60 = *Moringa oleifera* (2t/ha) + NPK 60-30-30 = *Moringa oleifera* (4t/ha) > Control. With the exception of the control T1 all the other treatment performed equally well, yields were in the range 3.37 – 4.27t/ha. The performances of the other treatments were not significantly different from each other.

Conclusion

From the first season harvest, the performance of biomass application was comparable to the full rate fertilizer of NPK 120-60-60. This indicates that either of the two species *Moringa* and *Gliricidia* could be applied with or without mineral fertilizer to growing maize at the rates indicated to improve soil fertility and increase yields. The study is on-going and data is being collected to ascertain further the effect of tree biomass in combination with inorganic fertilizers on maize yield. Component interaction between maize/ Gliricidia and maize/ Moringa is being studied. Other studies include hydraulic properties of soils under the different crop Biomas application rates

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2.3 ENVIRONMENTAL MANAGEMENT AND CLIMATE CHANGE PROGRAMME

2.3.1 Study Title: Impact of pesticides on some soil physico-chemical parameters and water quality from two plantations establishment in Ghana.

Research Team: G.W. Quansah, M.M. Apetorgbor, T. Peprah, F.M.Tetteh
Collaborating Institutions: FORIG,
Duration of Project: 2012

Introduction

During initial establishment of plantations, different herbicides are used by farmers to selectively remove or eliminate non-economic plant species which often compete with the tree saplings for light, water, space and nutrients. The use of these herbicides has been on the rise in recent years.

The accelerated use of agrochemicals has generated major adverse effects on the environment (Herath, 1998). These sprayed herbicides not only kill off vegetation at the time of treatment, but also persist in the soil or vegetation for between one to two years or more.

In Ghana, labour is becoming expensive and farmers will continue to use herbicides to suppress weeds but the effects on the soil, environment, water bodies and biodiversity is of little or no concern to them. There is also little research conducted on forest soil chemistry, soil microbial and plant communities on naturally occurring and herbicide-induced soils. The study therefore seeks to examine the effects of pesticides on some soil physico-chemical properties and water quality.

Objectives:

1. To characterize soils of the study areas based on their physico-chemical properties.
2. To examine the differences between herbicide polluted and intact soils
3. To assess the effects of herbicides on soil fertility and water quality under established plantations.

Methodology

Collection of soil and water samples

Soil and water samples were taken from the study areas (Mankrang and Afram Headwaters) in August 2012. Two composite soil samples were taken at 0 – 15cm and 15 – 30cm depths while water samples were collected in bottles and stored at 4 °C.

Laboratory Analysis

The following soil parameters were determined:

Soil pH was determined in a 1:1 suspension of soil and water using a HI 9017 microprocessor pH meter. Organic carbon was determined by a modified Walkley and Black procedure as described by Nelson and Sommers (1982). Total nitrogen was determined by the Kjeldalh digestion and distillation procedure as described in Soil Laboratory Staff (1984). Exchangeable bases (Calcium, Magnesium, potassium and sodium) in the soil were determined in 1.0 M ammonium acetate (NH_4OAc) extract (Black, 1986). Effective cation exchange capacity (ECEC) was calculated as the sum of exchangeable bases. Available phosphorus was determined by the Bray-1 method as described by Bray and Kurtz (1945). Particle size distribution was determined by the hydrometer method as described by Bouyoucos (1962). The parameters determined on the water were: pH, electrical conductivity (EC), nitrates (NO_3-N), ammonium (NH_4-N), calcium, magnesium, sodium, phosphorus, potassium, Mg:Ca ratio. Sodium Absorption Ratio (SAR) was calculated.

Results

Table 24 Some soil physico-chemical parameters

Treatment	Depth (cm)	pH	% O.M	ECEC (cmol/kg)	% Clay	Texture
Mankrang (T 1)	0 – 15	7.81	3.93	19.19	3.00	Sandy Loam
	15 – 30	7.79	2.40	6.64	4.70	Sandy Loam
Mankrang (T 2)	0 – 15	7.67	3.70	13.90	5.00	Sandy Loam
	15 – 30	7.48	2.55	8.17	8.00	Sandy Loam
Afram H. (T 3)	0 – 15	6.50	3.98	6.65	3.07	Loamy Sand
	15 – 30	6.27	3.50	7.14	3.33	Loamy Sand
Afram H. (T 4)	0 – 15	7.07	6.04	10.96	2.67	Loamy Sand
	15 – 30	7.09	5.25	11.04	3.33	Sandy Loam

Whiles lower soil pH and higher soil organic matter content favoured greater adsorption capacity of the Afram Headwaters soils which may promote pesticides accumulation, higher ECEC and clay content values favoured greater adsorption capacity of the Mankrang soils.

The EC (< 0.75m S cm^{-1}), SAR (< 10.0) Mg:Ca ratio (< 3.0)and NO_3^- (< 5.0mgL^{-1}) were within permissible levels suitable or safe for irrigation (Richards, 1954; Duncan et al., 2000). However, according to Duncan et al. (2000), P and K levels of the Mankrang Teacher's farm water sample had values that were higher than the permissible levels (> 0.4mgL^{-1} and > 20.0mgL^{-1}) respectively. Also pH values for Abofour Mere II and Abofour Mere Asuobia were not within the normal pH range (6.50 – 8.40) considered suitable of streams and groundwater for irrigation. Water sample from the Mankrang Teacher's farm is therefore not recommended for irrigation

Table 25 : Water chemical parameters

Sample	pH	EC	mg / litre				Mg/Ca	SAR
		mS/cm	Na	P	K	NO_3-N		
Tano S.	7.11	0.06	0.05	0.34	2.03	Trace	0.76	0.004
T. Farm	6.89	0.50	0.22	3.12	22.75	Trace	0.37	0.005
A. M. II	5.97	0.16	0.06	0.60	5.22	Trace	1.52	0.004
Afram N	7.10	0.17	0.03	0.18	2.17	Trace	0.85	0.001
Asuobia	6.17	0.05	0.04	0.23	1.26	Trace	0.41	0.004

Conclusions and recommendations

1. Lower soil pH and high OM content of the Afram Headwaters soils may promote pesticides accumulation due to their high adsorption capacity and are less likely to contaminate groundwater.
2. Mankrang soils per their pH and OM content may promote groundwater contamination.
3. ECEC and clay content would not significantly influence the adsorption of both Afram Headwaters and Mankrang soils and therefore pesticides adsorption will mostly depend on the organic matter content.
4. In both cases, the persistent use of pesticides in these areas would impact negatively on the soil and groundwater as well. It is recommended therefore that pesticides are used in moderation and an integrated approach of suppressing weeds should be adopted.
5. Water samples from the Mankrang Teacher's farm, Abofourmere II and Abofour Mere Asubima are not recommended for irrigation.

6. The study is running for the second year to quantify pesticide levels to determine the negative impact of these pesticides on soil and water quality.

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2.3.2 Study Title: Lead and cadmium pollutants at three sites in Ashanti

SRI Research Team: B. O. Antwi,

Collaborating Institutions: SARI,

Duration of Project: 2012

Background

Lead can be found in many places: the soil near highways and houses, lead paint, lead bullets, lead soldering. Lead poisoning can result from placing lead objects in your mouth, placing fingers in your mouth after handling lead, or from breathing dust that contains lead. Improper waste disposal and spills at hazardous waste sites may cause cadmium to leak into nearby water and soil. Inhaling cadmium-laden dust quickly leads to respiratory tract and kidney problems which can be fatal.

Methodology

The main pollutants considered were lead and cadmium. Three polluted sites were identified (Ahenema Kokobeng Legacy waste dump; Intiribuoho Lead acid recycling plant and Bremang). Composite and target samples from the soils and water resources were taken. Human exposure pathways were recorded and mitigation measures discussed with community leaders.

Results

The results (Table 26) showed that exposure of humans to lead and cadmium pollutants were through contact with the soil, inhaling dust blown particles and ingestion through the food chain. The concentration of lead to cadmium in the environment depended on the intensity of industrial activity within the sites. Considering the maximum acceptable limit of lead in water (10 µg/l) and 400 mg kg^{-1} in maize, a field close to the residential area on a refuse dump site were in excess of 770 mg ha^{-1}, Bremang lead acid legacy site had (7800 mg kg^{-1}) Surrounding fields of Ntiribuoho around KOADAYA lead-acid recycling site had (950 mg kg^{-1}) and water from dug outs within KOADAYA in excess of 1980 µg/l. EPA and Blacksmith Institute are initiating plans to rehabilitate the lead-acid sites. Cadmium was not a major pollutant except at Aheneba-Kokoben where the level of cadmium exceeded the maximum acceptable level (14 mg kg^{-1}) by 6 mg kg^{-1}. In the study areas, several people are exposed to dermal contact, ingestion and inhalation of heavy metals. Cumulative effect may be the cause of health problems associated with the young and the old.

Table 26. Results of lead and cadmium concentrations in some communities

Label	Acceptable levels Cd (mg kg^{-1})	Results Cd (mg kg^{-1})	Acceptable levels Pb (mg kg^{-1})	Results Pb (mg kg^{-1})
Ahenema Kokobeng-soil-composite-school ground	1.4	14.80	400	4.76
Ahenema Kokobeng-soil-target-maize in residence	1.4	4.12	400	1169
Ahenema Kokobeng-soil-composite-Apere site	1.4	20.80	400	15.92
Breman legacy lead-acid recycling site -soil-target-Target sector2	1.4	0.560	400	8238.08
Breman legacy lead-acid recycling site -soil-composite-Residential	1.4	0.426	400	1612.40
Ntiribuoho Section Upper Hill (Around Plant) Lead-acid recycling	–	–	400	1137.56
Ntiribuoho Primary School	–	–	400	36.12
Ahenema Kokobeng-water-target-stream	0.01 mg/L	0.036 mg/L	0.200 (mg/L)	0.383mg/L
Ntribuoho Ko-Adaaya Water Sample (well)	–	–	0.001/0.200 (mg/L)	1.020 mg/L

2.4 LABORATORY ANALYTICAL SERVICES PROGRAMME

The Institute's laboratories carried out physio-chemical analysis on soil samples for the Soil classification and mapping as well as their evaluation for agricultural, forestry and environmental management purposes. These samples were analyzed for research projects being implemented by the Institute, other sister institutions and the universities as well as private commercial farms, governmental and non-governmental organizations. Other samples as water, plant and fertilizer were also received for analyses.

Clients during the period could be categorized into the following groups:

Agriculture

- Small scale farmers
- Large scale commercial farmers (Oil Palm Estates – TOPP, BOPP, NORPALM, Pineapple plantations, Banana plantations (VOLTA), Jatrophar, Cocoa, Coffee, Tobacco, Cotton, Coconut)
- Research projects- CRI (Maize, rice vegetables, etc), FORIG (Natural resource management), SRI – Sawah Project, Fertilizer trials, microbiology projects

Environment

- Mining companies – Monitoring of regeneration of degraded lands
- Monitoring of degraded sites and establishement of oil palm plantations.
  (Goldfields Ghana Ltd, ANGLOGOLD Ashanti, Bogoso Gold Ltd (GOLDEN STAR BOGOSO/PRESTEA MINES)
- Re-vegetation of old tailings dams (RESOLUTE AMANSIE LTD)
- Monitoring of soil organic matter build-up.
- Monitoring of heavy metal content of food crops produced in mining areas.
- Phyto-remediation

Pollution monitoring

- Cyanide analysis of soil and water samples following spillage

- TCLP TEST (Toxicity characteristics leaching procedure) for arsenic in mine wastes
- NAG TEST (Net acid generation test) for acid rock drainage characterization.

TRAINING OF STUDENTS

Attachment training was conducted for students from KNUST, UDS, UCC, UG, Kwadaso, Damongo and Ejura Agric. Colleges as well as PhD students from Bonn University

CHALLENGES

The laboratory has obsolete equipment, inadequate glassware and laboratory reagents.

3.0 COMMERCIAL AND INFORMATION DIVISION (CID)

Introduction

The Commercial and Information Division (CID) of Soil Research Institute consists of the Research Commercialization, Data Management, Library, and Publication Sections.

Major Commercial activities undertaken during the year under review included land evaluation and soil survey for efficient land use planning, soil / plant /water and fertilizer samples analyses in the laboratory, soil related consultancy services, hiring of conference halls, hiring of vehicles, sale of maps and memoirs and sale of farm produce.

In all GH¢79152.63 was generated from research commercialization activities during the year under review as shown on the table below.

Table 27. Internally generated funds 2012

COMMERCIAL ACTIVITIES	GROSS AMT GH¢	EXPENSES GH¢	NET GH¢
Land evaluation/ soil survey	66,614.58	48,457.07	18,157.51
Laboratory analytical services	81,804.75	41,228.03	40,576.72
Consultancy services	3,702.00	1,239.00	2,481.00
Hiring of conference halls	1,450.00	---	1,450.00
Hiring of vehicles	1,920.00	---	1,920.00
Sale of maps and memoirs	3,165.00	178.60	2,986.40
Sale of farm produce	4,785.00	244.00	4,514.00
Other income	7,311.00	244.00	7,067.00
TOTAL	**170,743.33**	**91,590.70**	**79,152.63**

The Data Management section continued to manage the internet facilities and the Local Area Network as well as supervised the servicing of institutional computers.

The institute's **library** continued to provide both digital and manual library services to staff and other patrons as students and scientists from local and foreign institutions. The library also received books, periodicals, newsletters, journals, magazines and annual reports from both local and international partner institutions.

The Publication section also supported the library to provide information to enquirers seeking information on the country's soils, vegetation, land use and related subjects for research and development purposes. The section also rendered book binding and photocopying service to staff and Institute's clients. Appendix 1 shows publication produced in 2012.

4.0 ADMINISTRATION AND FINANCE

The Institute was managed by an eight-member Management Board chaired by Oheneba Adusei Poku, Akyempimhene, Kumasi (Appendix 4) as well as a 15 member Internal Management Committee chaired by the Director (Appendix 5). The Institute's staff strength stood at 294, made up of 33 senior members, 85 senior staff and 176 junior staff (Appendix 3). Total receipts of Ghana Government funds for the year was GH Cedis 4.7 million constituting about 55% of the approved budget. The amount was spent as per the table below;

Government of Ghana funds - 2012.

Type of expenditure	Expenditure (GHC)
1. Personnel Emoluments	4 706 378.68
2. Administrative Activities	-
3. Service Activities	-
4. Investment Activities	-
TOTAL	4 706 378.68

Appendix 1

PUBLICATIONS PRODUCED IN 2012

Refereed Journals Papers

R. N. Issaka , J. K. Senayah, E. Andoh-Mensah and Stella A. Ennin. 2012. Assessment of Fertility Status of Soils Supporting Coconut (*Cocus nucifera*) Cultivation in Western and Central Regions of Ghana. West African Journal of Applied Ecology, Vol. 20 (1), 2012. 47-56

S. E. Obalum., **M. M. Buri**, J. C. Nwite, Hermansah, Y. Watanabe, C. A. Igwe, and T. Wakatsuki (2012): Soil Degradation-Induced Decline in productivity of sub-Saharan Africa Soils: The Prospects of looking downwards the lowlands with the 'Sawah' Eco-technology. *Applied & Env. Soil Sci. Vol.* 2012: Article ID 673926, 10 pages, 2012.doi:10.1155/2012/673926.

S. E. Obalum., J. Oppong, J. C. Nwite, Y. Watanabe, **M. M. Buri**, C. A. Igwe, and T. Wakatsuki (2012): Long-tern effects of lowland 'sawah' system on soil physicochemical properties and rice yield in Ashanti region of Ghana. *Spanish Jour. of Agric. Research* 2012 10(3), 838 – 848.

Yeboah E., Antwi B.O., Ekem, S.O., Tetteh F.M., Bonsu K.O. Biochar for Soil Management: Effect on Soil Available N and Soil Water Storage" Accepted for publication in **Journal of Life Sciences, USA**

N. Kyei Baffour, E.T. Atakora, E. Ofori, B.O. Antwi. Estimation of Soil Erodibility and Rainfall Erosivity for the Biemso Basin, Ghana. Journal of the International Association for Environmental Hydrology

Dorgebetor, W. H.K., Dowuona, G. N.N., Danso, S. K. A., Amatekpor, J. K., Ogunkunle, A. O. and Boateng, E. (2012) Evaluation of Quality of Some Rehabilitated Mined soils within the Anglo-Gold-Ashanti Concession in Ghana. *International Journal of Geosciences 2012, 3, 50-61*

Boateng, E., Dowuona, G.N.N., Nude, P.M., .Foli, G., Gyekye, P. and Hashim M. (2012) Geochemical Assessment of the Impact of Mine tailings Reclamation on the quality of Soils at Anglo-Gold Concession, Obuasi, Ghana. *Research Journal of Environmental and Earth Sciences 4(4): 466-474*

Boateng, E., Yangyuori, M., Breuning-Madsen, H. and MacCarthy, D. S. (2012) Characterization of Soil Water Retention with Coarse Fragments in the Densu basin of Ghana. *West Africa Jnl. of Applied Ecology*. Accepted for publication in Vol. 21.

Parkes, E A, D. F. K. Allotey, E. Lotsu and E. A. Akuffo. Yields of five cassava genotypes under different fertilizer rates. International Journal of Agricultural Sciences ISSN: 2167-0447 Vol.2(5) pp 173-177, June 2012.

Conference Papers

Issaka R. N., **Buri M. M**., Kombiok J. M., Nagumo F., Omae H., Sakye-Annna E and Gaisie E. (2012). Effect of relay cover cropping on succeeding maize crop yield and soil nitrogen in different agro-ecological zones of Ghana. Paper presented at the Workshop on Collaborative Research Activities of JIRCAS in Ghana – Technologies to enhance rice production and to improve savannah agriculture in Africa with various approaches" held in Accra, Ghana on 27th Sept. 2012.

Buri M. M., Issaka R. N. and Wissuwa M. (2012): Evaluation of selected rice varieties on low P soils in the forest agro-ecological zone of Ghana. Paper presented at the Workshop on Collaborative research activities of JIRCAS in Ghana – Technologies to enhance rice production and to improve savannah agriculture in Africa with various approaches" held in Accra, Ghana on 27th Sept. 2012.

Tobita S., Nakamura S., Fukuda M., Nagumo F., Israel D., Awuni J., Avornyo V., Issaka R. N., **Buri M. M** and Eric A. (2012). Improvement of soil fertility with use of indigenous resources in rice systems of sub-Saharan Africa. Paper presented at the Workshop on Collaborative research activities of JIRCAS in Ghana – Technologies to enhance rice prouction and to improve savannah agriculture in Africa with various approaches" held in Accra, Ghana on 27th Sept. 2012.

Technical Reports

Buri M. M. (2012): Mid-term Review Report on 'Sawah', Market Access and Rice Technologies for Inland valleys (SMART- IV) Project (2012). CSIR-SRI/CR/BMM/2012/01

Antwi, B.O., and W.A. Adjare. Irrigation Feasibility report for Houtman Oil Palm (Draft Report)

Antwi, B.O., and W.A. Adjare. Rehabilitation of Dede Forest Reserve with Irrigated Paulonia; Tech (CSIR-SRI/CR/BOA/2012/04) October, 2012

Chapters in Refereed Books

S. Nakamura, R.N. Issaka, I.K. Dzomeku, M. Fukuda, **M.M. Buri**, V.C. Avonyo, E. Owusu-Adjei, J.A. Awuni and S. Tobita: Improvement of soils fertility with use of indigenous resources in lowland rice systems. *In* Soil Fertility**.** Edited by R. N. Issaka. Pp 33 - 44; ISBN 978-953-51-0873-3.

M. M. Buri, R. N. Issaka, J. K. Senayah, H. Fujii and T. Wakatsuki: Lowland soils for rice production in Ghana. *In* Crop Production Technologies. Edited by P. Sharma and V. Abrol. Pp 137-150; ISBN 978-953-307-787-1

Brochure

Dr. E. Yeboah (and other partners) produced Soil Testing Guide, 1st edition, 2012 in collaboration with Alliance for a Green Revolution in Africa (AGRA), GIZ and CABI and Ghana's Ministry of Food and Agriculture (MoFA),

Appendix 2

Workshops and Conferences:

CSIR-SRI led by B. O. Antwi	Hosted an International Training Programme in Sustainable Soil Resources Management, at CSIR - Soil Research Institute, Kwadaso-Kumasi from 27th to 31st August 2012. The training workshop was organized for 8 Senior Personnel selected from the Department of Agricultural Land Resources, Federal Ministry of Agriculture and Rural Development, Nigeria (FDLAR)
CSIR-SRI led by E. Yeboah	Hosted a Policy Innovation Systems for Clean Energy Security (PISCES) Joint Implementation Group (JIG) and International Food Policy Research (IFPRI) Biochar Workshop from 12-14th November 2012 at the Golden Tulip Hotel, Kumasi, Ghana Theme: Biochar production, soil fertility management and socio-economics: needs, opportunities and challenges. Participants were from United Kingdom, Kenya, Tanzania, America, India, Sri Lanka, USA, Vietnam and Ghana.
All CSIR-SRI Scientists	Undertook an introductory course on the use of "Decision Support System for Agro-Technology Transfer (DSSAT)" for soil and agronomic research in Ghana" from June 12 to 14, 2012, at the Soil Research Institute, Kwadaso-Kumasi.
M.M. Buri	Participated in a Workshop on Collaborative Research Activities of JIRCAS in Ghana – Technologies to enhance rice production and to improve savannah agriculture in Africa with various approaches" Accra, Ghana. September 2012
D. F. K. Allotey and Ben Ason	Attended a Stakeholders Workshop of the Ghana, Germany and Israel Trilateral Project. They presented a paper entitled "Soil fertility status of selected citrus orchards in Ghana: A case study in the Eastern and Central Regions" on 26th September 2012.

Appendix 3

STAFF MATTERS

STAFF STRENGTH

Staff Ranking	Kumasi	Accra	Total
Senior Members	27	6	33
Senior Staff	72	13	85
Junior Staff	165	11	176
T O T A L	264	30	294

DIVISIONS/SECTIONS MANPOWER POSITION

No.	Division	Senior Members	Technicians Senior / Junior	Admin/ Support.	Grand Total
1.	Soil Microbiology	4	2	6	12
2.	Soil Chemistry/Mineralogy	3	5	7	15
3.	Soil Genesis & Land Evaluation	4	6		10
4.	Soil Fertility & Nutrition Div.	6	10	42	58
5.	Soil & Water Management	4	1	10	15
6.	Commercial Information	4		8	12
7.	Administration	2		15	17
	Sections				
8.	Accounts & Stores			14	14
9.	Security & Watchmen			20	20
10.	SMR & Extension Farm		2	24	26
11.	Transport & Civil Workshop		1	15	16
12.	Station Maintenance		1	33	34
13.	Cartography		7	1	8
14.	Canteen			7	7
	1. Kumasi	27	35	202	264
	2. Accra	6	13	11	30
	Grand Total	33	48	213	294

NEW APPOINTMENTS:

Senior Members

No.	Name	Position	Effective Date
1.	Ephraim Sekyi-Annan	Research Scientist	08/08/2011
2.	Benjamin Ason	Research Scientist	01/02/2012
3.	David Ebo Ampah	Admin. Officer	03/07/2012

Senior Staff

NO.	Name	Position
1.	Mabel Awuah	Prin. Acct. Asst.
2.	Moses Nyako Amoah	Senior. Security Asst.
3.	Seth Adjei	Acct. Asst.
4.	Mark Danquah	Senior. Security Asst.
5.	Eric Asamoah	Prin. Tech. Officer
6.	Prince Charles Asante	Prin. Tech. Officer
7.	Ben Amoah	Prin. Tech. Officer
8.	Dora Ocran	Senoir Clerk

Junior Staff

No.	Name	Position
1.	Yaw Ayika	Labourer
2.	Boakye Ansah	Labourer
3.	Robert Asante Agyapong	Labourer
4.	Simon Martey	Labourer
5.	Emmanuel Sarkodie	Cleaner

Deaths

No.	Name	Position	Date
1.	George Adongo	Senior Workshop Superintendent	8/03/2012
2.	Sylvanus Ayem	Senior Security Officer	29/04/2012
3.	Stella Annie Agumeh	Chief Administrative Assistant	24/07/2012

RETIREMENT

Senior members

No.	Name	DATE Employed 1^{ST} APPT.	Position Held	Date Retired	Years Served
1.	P. Poku-Acheampong	01/08/91	Scientific info. Officer	01/12/12	21
2.	Benjamin Adiyah	05/09/86	Research Scientist	19/12/12	26

Senior staff

No.	Name	Date Employed 1^{ST} APPT.	Position Held	Date Retired	Years Served
1.	Emmanuel Agyei Kwartin	02/10/95	CAA	26/01/12	16
2.	K. Gyamfi Agyemeng	29/07/77	CTO	01/10/12	35
3.	Richard Boadu	02/06/76	CTO	01/06/12	36
4.	Julius Addo Tham	03/12/73	CTO	26/01/12	39
5.	Jacobson K. Adu	23/05/78	PWS	03/06/12	34
6.	J. B. Arthur	01/02/82	Snr. Sec. Officer	06/09/12	30
7.	E. S. Bani	26/03/77	Snr. Admin. Asst	12/12/12	35
8.	E. F. Sarpong-Konadu	27/09/82	Admin. Asst	21/09/12	30
9.	Ben Sam	01/02/77	Asst. Farm Manager	01/07/12	35
10.	Alfred Bioh	01/06/78	Asst. Farm Manager	15/12/12	34

Junior staff

No.	Name	Date Employed 1^{ST} Appt.	Position Held	Date Retired	Years Served
1.	Ibrahim Dauda	01/04/81	Asst. Overseer	01/07/12	31
2.	Kofi Boateng	01/02/82	Sup. Headman	01/07/12	30
3.	Kwasi Asumeng	01/10/79	Sup. Headman	01/07/12	33
4.	Comfort Donkor	04/02/86	Overseer	01/07/12	26

STUDY LEAVE

No.	Name	Position Held	Programme Studies	Institution or School	Period
1.	Sampson Adjei	Res. Scientist	Ph.D Soil Science	UG Legon	4 years 2006-2012
2.	Isaac Owusu Ansah	Snr. Te ch. Asst.	B.Sc Agric Science	University of Cape Coast	4 years 2009-2013
3.	Stephen Wiredu	Technical Officer	Dip. In Gen. Agric	K.A.C., Kumasi	2 years 2011-2013
4.	Dorothy Aponye	Overseer	Cert. In Gen. Agric	K.A.C. Kumasi	2 years 2011-2013
5.	Kwabena A. Nketia	Technologist	M. Sc. Soil Science	UG Legon	2012-2014
6.	K. Andoh-Pahyin	Snr.Tech. O.	B. Sc. Lab. Tech	Univ of Cape Coast	2012-2014
7.	Thomas Afreh	Overseer	Cert in Agriculture	Ejura Agric. College	2012-2013
8.	Peter Ofori	Overseer	Cert in Agriculture	Ejura Agric College	2012-2013

RESIGNATION

Dr. B. B. Aligebam a Research Scientist went on voluntary retirement.

List of Students on Industrial Attachments

1.	Danquah Justice Boafo	KNUST
2.	Owusu Victor Kaakyire	KNUST
3.	Owusu A. Alexander S.	KNUST
4.	Solomon Adusi Poku	University of Education, Kumasi
5.	Eva Dede Anyasor	Sunyani, Polytechnic
6.	Osei Afrifa Kennedy	UCC
7.	Farouk Adebisi	UCC
8.	Nana-Osei Prempeh	University of Education, Kumasi
9.	Asamoah Simon	KNUST
10.	Banahene Nicholas	KNUST
11.	Golomeke Divine	KNUST
12.	Amofa Boateng Agyei	UDS, Nyankpala

13.	Agnes Owusu Ansah	UDS,Wa
14.	Korah Lucy	Sunyani, Polytechnic
15.	Musiliyetu Hamza	University of Education, Kumasi
16.	Antwi A. Randy	UDS, Nyankpala
17.	Maltilda Asamoah	
18.	Eunice Amposem	University of Mines and Technology
19.	Osei Owusu Sarah	UDS, Nyankpala
20.	Nadia Yeboah Amoateng	Garden City University College
21.	Agbenorhevi Enyonam Adzo	KNUST
22.	Solomon Osei	
23.	Asare Kwabena Attrams	Kumasi, Polytechnic
24.	Ampaw Michael Twum-Antwi	Kumasi, Polytechnic
25.	Osei-Wusu Emmanuel	KNUST
26.	Abigail Bannor	KNUST
27.	Osei Bonsu Edaward	KNUST
28.	Antwi Agyei Prince	KNUST
29.	Issah Rabiatu Jumai	KNUST
30.	Opoku Benjamin Duah	KNUST
31.	Antwi Bernice	KNUST
32.	Bosompem Richael Akosua	KNUST
33.	Mawusi Collins	KNUST
34.	Yeboah Jones Daniel	
35.	Amoem Benjamin	UDS, Wa
36.	Adjoa Dwamena Insiful	University of Ghana, Legon
37.	Appiah Joseph	UDS, Nyankpala
38.	Ivy Joy Kottoh	UDS, Nyankpala
39.	Agyei Yeboah Mavis	Sunyani Polytechnic
40.	Serwaa Eva Abena	Koforidua Polytechnic
41.	Oteng-Amponsah Joseph	Koforidua Polytechnic
42.	Emelia Asabere	Koforidua Polytechnic
43.	Anita Akowuah	Koforidua Polytechnic
44.	Yeboah Asiamah	Koforidua Polytechnic
45.	Phillis Boateng	MUCG
46.	Mumuni Zackaria	MUCG
47.	Gifty Guriyire	MUCG
48.	Amakwaa Mabel	MUCG

List of National Service Personnel

1.	Aaron Owusu Badu	KNUST	17^{th} September, 2012
2.	Prince Addai	KNUST	17^{th} September, 2012
3.	Kwaku Korankye	KNUST	20^{th} September, 2012

4.	Edmund Arthur	UDS, Nyankpala	20th September, 2012
5.	Anima Faustina	KNUST	1st November, 2012
6.	Terkepetey Dorcas	University of Ghana, Legon	6th January, 2013
7.	Owusu Godfred	KNUST	24th September,2012

Visitors

1.	Dr. Wilson A. Agyare	Dept of Agric Eng./WASCAL, KNUST
2.	Mr. Bernard N. Baatuuw	KNUST
3.	Ahouansou D. N. Mausice	KNUST, WASCAL Programme
4.	Dr. Amadou Laonli	KNUST, WASCAL Programme
5.	Akpa You Lucette	KNUST, WASCAL Programme
6.	Halimalou A. Toure	KNUST, WASCAL Programme
7.	Badmos B. Kaleem	KNUST, WASCAL Programme
8.	Nat Owusu	KNUST, WASCAL Programme
9.	Demba N. A. Trawally	KNUST, WASCAL Programme
10.	Hannah V. Adzraku	KNUST, WASCAL Programme
11.	Traore Sruleymone S.	KNUST, WASCAL Programme
12.	Thiombiano Boundia	KNUST, WASCAL Programme
13.	Dr. A. B. Salifu	CSIR, Head Office
14.	F. Nagumo	JIRCAS Tsukuba, Ibaraki, Japan
15.	Saoshi O.	JIRCAS Tsukuba, Ibaraki, Japan
16.	Azusa Fukuki (RESTEC)	Minatorku Tokyo, Japan
17.	Tomoyuki Kawashima	JIRCAS, Tsukuba, Japan
18.	Satoshi Nakamura	JIRCAS Tsukuba, Ibaraki, Japan
19.	Hide Omae	JIRCAS Tsukuba, Ibaraki, Japan
20.	Satoshi Tobita	JIRCAS Tsukuba, Ibaraki, Japan
21.	V. M. Anchirinah	CRIG, Tafo

Appendix 4

MEMBERSHIP OF MANAGEMENT BOARD, 2011

1.	Oheneba Adusei Poku	-	Chairman, Akempimhene, Kumasi
2.	Dr. (Mrs.) R.E.M. Entsuah-Mensah	-	Member, Deputy Director-General, CSIR Head Office, Accra.
3.	Mrs. L. Bedu Addo-Mensah	-	Member, Area Manager, Agricultural Development Bank, Kumasi
4.	Mr. T.F. Asare	-	Member, Asare Farms Limited, Kumasi
5.	Mr. George Owusu Afriyie	-	Member, Manager, Pacific Savings & Loans Limited, Kumasi.
6.	Dr. Hans Adu-Dapaa	-	Member, Director, CSIR- Crops Research Institute, Kumasi
7.	Dr. J. O. Fening	-	Member, Director, CSIR-Soil Research Institute, Kwadaso-Kumasi
8.	Mrs. Hectoria Tsaku-Harker	-	Secretary, Administrative Officer, CSIR-SRI, Kwadaso-Kumasi

Appendix 5.

MEMBERS OF THE INTERNAL MANAGEMENT COMMITTEE

1.	Dr. J.O. Fening	-	Director/Chairman
2.	Mr. E. Boateng	-	Deputy Director/Head, Soil Research Centre, Accra
3.	Dr. K. O. Asubonteng	-	Head, Soil Fertility Division
4.	Dr. F. M. Tetteh	-	Head, Laboratory Analytical Services Division
5.	Dr. B. O. Antwi	-	Head, Soil and Water Management Division
6.	Mr. E. Yeboah	-	Head, Soil Microbiology Division
7.	Mr. J.K. Senayah	-	Head, Soil Genesis, Survey and Class. Div.
8.	Mrs. H. Tsaku-Harker	-	Head of Administration
9.	Mr. P. Poku Achampong	-	Head, Commercial and Information Division
10.	Mr. K. Yiadom	-	Head, Accounts and Stores Section
11.	Mr. S.B. Atiemo	-	Security and Station Maintenance Section
12.	Mr. James Oppong	-	RSA Representative
13.	Mr. Edward Kissi	-	TUC Representative
14.	Mr. Ato Essien	-	SSA Representative
15.	Mr. S.J. Obeng	-	Secretary