# PROCEEDINGS OF THE FIRST INTERNATIONAL WORKSHOP

# ON "SAWAH" ECO-TECHNOLOGY AND RICE FARMING IN SUB-SAHARAN AFRICA

**22nd - 24th NOV. 2011**

**KUMASI, GHANA**

Editors: M. M. Buri, T. Wakatsuki, R. N. Issaka & S. Abe

# PROCEEDINGS OF THE FIRST INTERNATIONAL WORKSHOP

# ON "SAWAH" ECO-TECHNOLOGY AND RICE FARMING IN SUB-SAHARAN AFRICA

22nd- 24th NOV. 2011

KUMASI, GHANA

June, 2012

ISBN: 978 - 9988 - 1 - 6778 - 3

**Published By:**

Faculty of Agriculture,
Kinki University, Nara 631-8505, Japan

and

Soil Research Institute
Academy Post Office, PMB,
Kwadaso, Kumasi, Ghana



Designed & Printed in Ghana by:
**NII NAI CREATIONS**
233-24-333-9936
e-mail: fennts_nii@live.com

## SPONSORS

FACULTY OF AGRICULTURE,
KINKI UNIVERSITY, NARA 631-8505, JAPAN

CSIR - SOIL RESEARCH INSTITUTE, ACADEMY POST OFFICE, KWADASO - KUMASI, GHANA

JAPAN INTERNATIONAL RESEARCH CENTRE FOR AGRICULTURAL SCIENCES (JIRCAS), TSUKUBA, JAPAN

AFRICA RICE CENTRE 01 B. P. 2031, COTONOU BENIN

# FOREWORD

The first international workshop on 'Sawah' eco-technology and rice farming in sub-Saharan Africa took place in Ghana under the auspices of the Kinki University of Japan and CSIR-Soil Research Institute. The workshop was a historic event as it brought together various players, not only in rice production but also environmental management as well. Major stakeholders that attended the workshop included policy makers, scientists, extensionists, environmentalist, farmers, opinion leaders and the media from seven (7) different countries.

Many papers were presented which covered major aspects of the 'sawah' system such as (i)Overview of 'sawah' eco-technology and (ii) Fundamentals and principles of the 'Sawah' Eco-technology such as site selection, system design, development, agronomy, and farmers' empowerment. Selected and reviewed papers are being published as proceedings. Participants had the opportunity to go on a field trip where the major aspects of 'sawah' development and management were demonstrated and observed. The general context of papers presented covered both research findings and case studies on sustainable rice production techniques under the 'sawah' system and environmental management.

After lengthy deliberations on how to chart the way forward, the workshop has come out with recommendations which are also included in the proceedings. It is the humble hope of the organizers of the workshop that for sustainable rice production and effective environmental preservation, information and results generated under the 'sawah' systems will be effectively disseminated for the benefit of all stakeholders. It is our further hope that information shared at the workshop will open the necessary avenues for the rapid transformation of rice production and the realization of the rice green revolution in sub-Saharan Africa. The 'sawah' system can serve as a gate way for this revolution.

We are very grateful to the organizations which helped in sponsoring this workshop: Kinki University, Nara, Japan; CSIR-Soil Research Institute, Kumasi, Ghana; Japan International Research Centre for Agricultural Sciences (JIRCAS) Tsukuba, Japan and Africa Rice Centre, Cotonou, Benin.

Prof. Toshiyuki Wakatsuki
(Chairman, Organizing Committee)

## SECTION I



## SECTION II



## SECTION III

# SECTION ONE
# OPENING CEREMONY

# TABLE OF CONTENT

## WELCOME ADDRESS BY DIRECTOR-GENERAL OF THE COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH (CSIR-GHANA).

**Alhaji Dr. ABDULAI B. SALIFU**

Mr. Chairman, Honorable minister of Environment, Science and Technology, Executive Director of JIRCAS, Visiting Directors Scientists from Japan and sister West African Countries, Representative of Africa Rice, Renowned Scientists and Research Fellows, Policymakers, Stakeholders and Industrialists, Directors of CSIR Institutes, Farmers, Members of the Press,

It is a great pleasure from me to you all to the international workshop on "SAWAH" Eco-technology and Rice Farming (SERIF) in Ghana, Nigeria and sub- Saharan Africa. We are honored this morning to have our Honorable Minister of Food and Agriculture, Honorable Mr. Kwesi Ahwoi, who chairs this function, the Honorable Minister of Environment, Science and Technology, Honorable Sherry Ayitey, and other dignitaries, policymakers, renowned researchers and scientists from Japan, Nigeria ,Benin ,Togo and Ghana. On behalf of the Council for Scientific and Industrial Research (CSIR-Ghana) and my own behalf, I welcome you all to this very important workshop. I have no doubt that your presence and contribution at this workshop will impact positively on rice farming in sub-Saharan Africa.

Mr. Chairman: Rice production in West Africa is outstripped by consumption. No country in West Africa is self-sufficient in rice production. Per capita rice consumption continues to show an upward trend, especially in urban areas. In the decade 1979-81 to 1989-91, the demand for rice in West Africa almost doubled, growing from five million tons in 1979-81 to over nine million tons in 1989-91. In Ghana, commercial rice imports accounted for about 61% of rice consumption per annum over the four years 2000 to 2003.Current estimate indicate that imported rice accounted for about 70% of rice consumed in Ghana averaging about 7 million metric tons in 2007, 2008, and 2009.The self-sufficiency rate in rice production in Ghana is about 30% leaving a short fall of 70%, estimated at about 450 million dollars, to be imported annually to augment local rice supply. Several efforts have been made in the past and present to boost production but we are still challenged by issues such as lack of good quality seed and inappropriate processing technology which does not allow domestically processed rice to match the quality of imported rice in terms of homogeneity and cleanliness. Ghanaian rice consumers are very choosy and are ready to pay a higher price for imported and well packaged rice.

CSIR-Ghana is the largest scientific research organization in the country, with thirteen (13) research institutes strategically spread nation-wide; each of which has a mandate covering specialized areas of importance for growth and development of the nation. Through its institutes the CSIR has contributed immensely to national socio-economic development.

CSIR technologies underline varieties deployed originate almost exclusively from CSIR institutes of the Crops Research and Savannah Agricultural Research Institutes respectively. In recent times these Institutes have in addition to several lowlands rice varieties, released at least NERICA varieties destined for upland production, which are being grown by more than 25,000 farmers country-wide.

The huge expenditure encumbered by West African countries on rice importation is worrying for its negative socio-economic effects. It means countries with largely poor households spend millions of scarce foreign exchange on rice imports only to crowd out local farmers and processors from the domestic market, resulting in job losses and increased poverty and food insecurity, especially among rice and other-chain actors.

There is therefore an urgent need for technical innovation to promote efficiency in local rice production through the dissemination of new technologies, in collaboration with rice farmers to increase productivity in local rice production, generate employment, improve incomes, reduce poverty, increase food security and ensure environmental sustainability. Ladies and gentlemen the *Sawah* eco-technology has the capacity to assist in the achievement of these goals.

Mr. Chairman, Honorable Minister; The *Sawah* eco-technology provides a boost to lowland rice production by effectively managing land, water control and nutrients. *Sawah* in brief refers to a system in which a rice field is demarcated, bundled with water inlet and outlet, puddled and leveled. It is developed using a power tiller and simple farm tools, all which can be within the means of small holder rice farmers. The *Sawah* system improves the productivity of rice by reducing weed incidence and increasing rice yields. On the whole *Sawah* Eco-technology has been observed to improve fertilizers and irrigation efficiency, improve water shortage, soil nutrition, especially nitrogen and phosphorus supply, neutralizes acidity and alkalinity and improves micronutrients supply. The system is also environmentally friendly, minimizes erosion, reduces land degradation and increases nutrient-use-efficiency.

Mr. Chairman, Distinguished Ladies and Gentlemen: Much as we will have wished to see this productivity-enhancing technology up-scaled across a wider catchment, there are a couple of teething challenges that need to be overcome. Some of the major challenges to the adoption of the technology are funding, lack of institutional support by ministries, departments and agencies, lack of credit to purchase machinery to facilitate ready, faster, and effective land preparation and cultural constraints, including land tenure systems.

Mr. Chairman: Fortunately this workshop provides us with an opportunity for our policymakers, industrialists, research scientists, research fellows and farmers to discuss and exchange information and experiences towards the scaling-up and dissemination of the *Sawah* Eco-technology. On a personal note I wish to underline emphatically that the drive towards self-sufficiency in domestic rice production in African countries is possible with the *Sawah* Eco-technology.

Finally, Mr. Chairman and Distinguish Ladies and Gentlemen: on behalf of the Council for Scientific and Industrial Research (CSIR-Ghana), the organizers of this workshop and on own behalf; I once again welcome you all to this important workshop. Hopefully the outcome will lead to the development of strategies to enhance the application of the *Sawah* Eco-technology across a wider agro-ecology and other rice growing regions in the West African sub-region and sub-Saharan Africa.

I wish you successful deliberations. Thank you very much.

## INTRODUCTION OF SAWAH ECO-TECHNOLOGY BY THE LEADER OF THE SAWAH PROJECT AND PROFESSOR AT SCHOOL OF AGRICULTURE, KINKI UNIVERSITY, JAPAN: Prof. T. WAKATSUKI

Honourable Minister for Environment, Science and Technology, Director General of the Council for Scientific and Indusdtrial Research (CSIR), Mr. Chairman from the Ministry of Food and Agriculture, Distinguished Guests, Ladies and Gentlemen,

I am very delighted that we are gathered here today with the sole purpose of improving, promoting and enhancing rice production for ensured food security, under the *Sawah* system. What is *a Sawah*? *Sawah* is farmers' made structures and systems to control water and conserve soils in order to maximize and sustain rice yield. *Sawah* is like a factory to produce paddy rice. If we have good *Sawah*, we can produce more paddy rice.

What is a *Sawah* eco-technology? *Sawah* ecotechnology offers farmers skills and technology on how to improve their agricultural land, in terms of water and soil conditions. Thus good high yielding rice varieties will perform well under proper fertilization and effective use of agrochemicals. Governments' irrigation and drainage projects can only be effective under farmers' *Sawah* eco-technology and skills. The most important thing is that *Sawah* eco-technology enpowers farmers. Farmers can develop their own personal irrigated rice fields by themselves without necessarily waiting for government support. Thus the *Sawah* ecotechnlogy has the potential for the realization of the long awaited green revolution in Ghana, Nigeria, Togo, Benin, and West Africa as a whole.

Ladies and Gentlemen, What is eco-technology?
The target of eco-technology is to improve rice growing environment to maximize the potential of rice varieties. Biotechnology can improve rice variety, while ecoetchnology will improve rice environment. During the last 40 years, major research on rice development has mainly focused on varietal improvement and largely neglected ecosystem improvement. Agriculture must integrate biological science and technology as well as ecological/environmental science and technology. Therefore both biotechnology and ecotechnology have to be developed in a balance way so as to be able to increase and sustain rice production.

Ladies and gentlemen! Finally I would like to thank sincerely and deeply the following people: the late Dr. Ernest Otoo of Crops Research Institute, late Dr. R. D. Asiamah of Soil Research Institute, and late Dr. J. Cobbina of Forest Research Institute of Ghana. The *Sawah* eco-technology research started with them in 1994 and officially ended in 1997 as JICA/CSIR *Sawah* Project. The three of them, I believe are in heaven now and I am confident they would be congratulating themselves and we all gathered here, on this 1st International *Sawah* eco-technology workshop. I thank you all and wish you a successful workshop.

## ADDRESS BY JAPAN INTERNATIONAL RESEARCH CENTER FOR AGRICULTURAL SCIENCES (JIRCAS) LAISON OFFICER FOR AFRICA. Dr. TETSUJI OYA.

Honorable Minister of Environment, Science, and Technology, Director General of CSIR, Distinguished guests, distinguished farmers, Ladies and Gentlemen,

It is my great pleasure to be here to participate in this workshop on "Sawah" eco technology and rice farming in Sub-Saharan Africa'. With increasing demand for rice in Africa, it has become more important to increase rice production. This workshop is important to understand how we can increase rice production in Africa. This year, JIRCAS started a new mid-term plan for 5 years. We have three research programs, namely 'Environment and natural resource management', 'Stable food production', and 'Rural livelihood improvement'. Under the 'Stable food production' program, we have one flagship project, namely 'Development of rice production technologies in Africa'.

As you may know, the main project site is Ghana, collaboration with CSIR, MoFA, and Universities. This month, there were several meetings focusing on rice production in Africa. One is the 4th CARD general meeting held in Kampala, Uganda on 8th and 9th November, 2011 At the CARD meeting, it was shown that small scale mechanization is more effective and more efficient compared to large scale mechanization. We should carefully consider it. I hope we can get relevant information from this workshop.

Another is JIRCAS symposium held in Tsukuba, Japan last week on 14th and 15th November, 2011 The title of the JIRCAS symposium is, 'Trends of international rice research and Japanese contribution –Support to GRiSP (Global Rice Science Partnership) and CARD (Coalition for African Rice Development). I would like to share with you some of the key discussion at the symposium: (i). Monitoring system and feedback is important, (ii). Weed is one of the most serious problems in rice production and (iii). Not only breeding and genetics, but also ecological and environmental improvements for rice production are important.

I hope this workshop will bring us some suggestions on those discussions. I further hope the outcome and results of this workshop will be shared and disseminated among all stakeholders to increase rice production in Africa.

Thank you very much.

## ADDRESS BY AFRICA RICE REPRESENTATIVE
## Dr. SANDER ZWART
## PROJECT COORDINATOR, SMART-IV

Ladies and Gentlemen,
On behalf of the Director General of the Africa Rice Center in Cotonou, Benin, I wish you a warm welcome to the first international workshop on 'Sawah' System Development.

The Africa Rice Center or Africa Rice in short, was created in 1971 by 11 African countries and is a true African organization. It started as the West African Rice Development Organization (WARDA). It has become a leading pan-African research organization working to contribute to poverty alleviation and food security in Africa through research, development and partnership activities. It is one of the 15 international agricultural research centers supported by the Consultative Group on International Agricultural Research (CGIAR). Three years ago, the institute changed its name to the current Africa Rice Center following the membership of countries not located in West-Africa. Today its membership comprises 24 countries, covering West, Central, East and North African regions, namely, Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Côte d'Ivoire, Democratic Republic of Congo, Egypt, Gabon, the Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Madagascar, Mali, Mauritania, Niger, Nigeria, Republic of Congo, Senegal, Sierra Leone, Togo and Uganda.

Since 2009 Africa Rice is involved in 'Sawah' System Development. The SMART-IV Project, which is supported financially by Japan's Ministry of Agriculture, Forestry and Fisheries (MAFF), started in October 2009 to examine the potential of 'sawah' technology transfer and 'sawah' system development (SSD) in inland valleys in African environments. In Nigeria and Ghana, 'Sawah' System Development was initiated in the 90's. The SMART-IV project closes the geographical gap between both countries by focusing on Togo and Benin. It is expected to benefit from the experiences from researchers and developers in these countries. This workshop is part of this process of knowledge transfer. Currently 10 employees of the extension services in Benin and Togo are present here in Kumasi to follow and train on 'Sawah' System Development. The training is organized by the Soil Research institute of Ghana.

Ladies and gentlemen, Africa Rice is happy to be part of this workshop and it is a great pleasure to be here. I wish you a very productive workshop.

**ADDRESS BY A REPRESENTATIVE OF NIGERIA SENIOR AGRIC. SERVICES ADVISER, NATIONAL THIRD FADAMA PROJECT Dr. AYODELE A. ADENIYI,**

Mr. Chairman, Honorable Minister of Environment, Science, and Technology, Director General of CSIR, Directors of CSIR and MoFA, Scientists, distinguished guests, distinguished farmers, Ladies and Gentlemen,

The Federal government of Nigeria will like to be associated with the 1st International workshop on "*Sawah*" Eco-technology and Rice Farming in sub-Saharan Africa taking place in Kumasi, Ghana.

Rice is one of the pilot crops of Nigeria Incentive Risk Sharing Coordination Agriculture Lending (NIRSAR) program designed to increase food production and stop importation Ghana is similar to what obtains in Nigeria. In a recent ministerial briefing in Nigeria, it was mentioned that the country is second largest importer of rice and as such, conscious efforts be made to change the scenario.

At the moment, average yield of rice on farmer's field is between 1.5 - 2.0 tons per hector. The introduction of *Sawah* technology will go a long way in yield increases under a proper water and land management regime. *Sawah* technology in Nigeria is anchored in the National Centre for Agricultural Mechanism (NCAM) in partnership with Kinki University of Japan with collaborative effort with the National Fadama Office. The technology is being demonstrated in 13 pilot states (out of 36 states and Federal Capital Territory of Nigeria). Reports received indicate high increases in yield are being achieved. Reports' coming in from the States show 7.2 tons per hector in the north-west, 6.5 tons per hector in the south-east and 3.5 tons per hector in the south-west.

The institutional arrangements for scaling up the *"Sawah"* technology exist in the country through the network of the National Fadama Coordination Office. The Fadama III Project is being implemented in all the states of the country.
Because of the importance we attach to this workshop, the Nigerian team this workshop comprises technocrats and farmers. On behalf of the team, I wish you all happy and fruitful deliberations.

## OBJECTIVES OF WORKSHOP BY DIRECTOR, CSIR - SOIL RESEARCH INSTITUTE Dr. J. O. FENING

Mr. Chairman, Director General of CSIR, Prof. Wakatsuki of Kinki University, Representative of Africa Rice, JIRCAS Laison Officer for Africa, Directors of CSIR Institutes, Directors of MoFA, Distinguished Scientists, Farmers, Members of the Press, Ladies and Gentlemen,

The *Sawah* technology for rice production advocates for effective nutrient utilization and water management for increased rice production in lowlands. The system embraces research and extension to conserve soil fertility depletion and improve the livelihood of farmers through the use of local and affordable resources. The stystem is also environmentally friendly as soil disturbance is very minimal during land preparation. Over 2000 farmers have been beneficiaries to the system and are currently enjoying higher yields of > 6.0 tons per hector. This is a significant improvement in yield when compared to the traditional system where average yields hardly exceeded 1.0 ton per hector.

Research in the sawah system has been on-going in close collaboration with a wide range of partners incluging: extension, farmer-groups, researchers in Nigeria and the private sector who are gathered here with the following objectives among others:

(i) to showcase the principles and practices of the sawah system,

(ii) to share knowledge and experiences from research and farmers view point and identify gaps for re-dress,

(iii) to promote the technology as the best option currently for lowland rice production in the sub-region and

(iv) to effect government policy directives in the promotion and adoption strategies of improved technologies such as sawah, if self sufficiency in rice production and guaranteed food security are to be achieved.

The yield between actual and achievable is very wide currently and I am convinced that with a wider adoption of sawah, this gab will very soon be [illegible] significantly. I thank you all very much.

# KEYNOTE ADDRESS DELIVERED BY THE MINISTER OF ENVIRONMENT, SCIENCE AND TECHNOLOGY (MEST), GHANA.

## Hon. SHERRY AYITTEY

Mr. Chairman, Director- General of CSIR, Representative of Kinki University (Prof. Wakatsuki), Representative of Africa Rice, Representative of JIRCAS, Representative of JICA, Directors of CSIR Institutes, Directors of MOFA, Distinguished Research Scientists, Dear Farmers, Members of the Press, Ladies and Gentlemen,

It is a pleasure for me to join you in the first ever international workshop to be held on the "Sawah" eco-technology. I wish to sincerely thank the Kinki University and the CSIR for making it possible for me to be part of this important program. I have no doubt in my mind that this workshop will mark yet another milestone in the research and development activities of the CSIR of Ghana, Africa Rice, Kinki University, JIRCAS and the collaborative partners in Nigeria and other countries within the sub-region.

Mr. Chairman, since the success of green revolution in Latin America and in Tropical Asia in the 1970s, similar research oriented activities for a green revolution has intensively and extensively been conducted in sub-Saharan Africa (SSA).However, up to date, the green revolution is yet to be realized. Rice is an important staple food for all parts of SSA and instead of the crop being grown in these countries where people can be employed, rural incomes raised, poverty reduced and food security ensued, rice is rather mainly imported into these countries, even though many countries in the sub-Saharan Africa have suitable environments for its' production. While International research organizations like Africa Rice in collaboration with NARS of various countries have developed innovative technologies for rice production, a successful path to a green revolution is still not clear to SSA.

Mr. Chairman, even though there have been several research concepts to improve natural resource management, there seem to be no clear research concept on how to improve resources such as soil and water conditions at the farmers field level. The "Sawah "eco-technology is one of such missing concepts designed to improve natural resource management in majority of African rice farms.

Ladies and Gentlemen, I am reliably informed that the "Sawah" eco-technology concepts can accelerate improvements in effective natural resource management, minimize environmental degradation and increase soil productivity under African conditions. Under uneven distribution of rainfall due to climatic conditions, the "Sawah" technology has simple but effective ways of harvesting water for use at farm level. SSA has an abundance of inland valleys, where "Sawah" eco-technology can be easily practiced. I am concerned that increase in severity of the loss of biodiversity, desertification and land degradation, exacerbated by the effects of climate change are major problems that countries have to address with respect to food security.

I note that the intensity of desertification of most Africa's arable land is a serious challenge for sustainable development in Africa. Most of the land in Africa is prone to land degradation and suffers the worst impacts of drought, desertification and deforestation, with 65 percent of the population affected. In this regard it is important to recognize the economic and social significance of land, particularly, its contribution to growth, food security, and poverty eradication, and step up efforts to effectively implement initiatives at local, sub regional, regional and nation levels to combat these problems, in order to promote sustainable land management and to reinforce north-south and south-south cooperation.

Mr. Chairman, Africa is characterized by highly variable rainfall and an uneven distribution of water resources, which is exacerbated by the effects of climatic change.

Mr. Chairman, drought in grain-producing countries, reduced crop yields, depleting cereal stocks and the multiple demands on existing stocks for human and animal consumption have resulted in persistent high food prices in many African countries. While the interventions undertaken jointly with affected communities and the international community have boosted food output, am concerned about the high cost of food in Africa. It is, therefore important, to take measures to ensure that the benefits derived from such efforts and initiatives trickle down and contribute positively to reducing hunger and poverty. We invite developed countries to provide developing countries with sound technologies, particularly biotechnologies, bearing in mind the precautionary principles, to increase production in the agricultural sector.

Mr. Chairman, ladies and Gentlemen, African lowlands are quite diverse with different environmental settings. It is my hope therefore that, this workshop will come out with suitable site-specific development and management technologies which can be easily disseminated for their effective and sustainable utilization. The development of such technologies and their management by local farmers through self propelled efforts and the use of small-scale equipment such as power tillers are needed under African conditions, to help mitigate the effect of climate change on our natural resources particularly the soil. It is therefore prudent that for sustainable agricultural production and the realization of the green revolution in the sub-region, there is the urgent need for a balance between technology development and its application. There needs to be a balance between varietal improvement through bio-technology and environment improvement through eco-technology. For quite some time now, more emphasis has been laid on bio-technological research and technology development, to the neglect of eco-technological research and technology development in sub-Saharan Africa.

The "Sawah" eco-technology has been observed to improve fertilizer use efficiency, irrigation efficiency, improved nutrient supply especially nitrogen and phosphorus, neutralize acidity as well as alkalinity, and improve micronutrients supply. The "Sawah" system of rice production therefore seeks to improve on lowland rice production by helping to effectively manage land, control water and nutrients to boost local rice production. Results have been very good so far, with average yields of 5-7tons/ha being very common among "Sawah" farmers across locations. I hope this workshop will critically examine its applicability within a wider agro-ecology as well as scaling it up to cover the sub region.

Mr. chairman, the government and people of Ghana are very grateful to Japan Society for Promotion of Science; Ministry of Education; Culture; Science and Technology; Ministry of Agriculture; Fisheries and Forestry and Japan International Cooperation Agency, for providing funding that led to the development of the" Sawah" technology. We are also grateful to all other research organizations and scientists who collaborated with their colleagues in Ghana to make this dream come true. I have been informed that some of the major challenges of the adoption of the technology are lack of funding, lacking of institutional support, cultural constraints (land tenure) and lack of credit lines to purchase machinery.

The Ministry of Environment, Science and Technology(MEST) and the Ministry of Food and Agriculture will work closely together to accelerate rice production while also protecting the environment by putting in place the necessary legislative and policy frameworks geared towards a faster adoption of environmentally friendly technologies like "Sawah".

I thank you very much and wish you a successful workshop.

# SECTION TWO
# SCIENTIFIC PRESENTATIONS

## *Table of Content*

# Multi-Functionality of '*Sawah*' Eco-Technology: Why '*Sawah*'-Based Rice Farming is Critical for Africa's Green Revolution

T. Wakatsuki[1], M.M. Buri[2], R. Bam[3], O.I. Oladele[4], S.Y. Ademiluyi[5], I.I.Azogu[5] and C. A. Igwe[6]

[1]*School of Agriculture, Kinki University, Nara 631-8505, Japan ;* [2]*CSIR-Soil Research Institute, Kumasi, Ghana ;* [3]*CSIR-Crops Research Institute, Kumasi, Ghana ;* [4]*North West University, Mafikeng Campus, Mmabatho 2735, South Africa ;* [5]*National Center for Agricultural Mechanization, Ilorin, Nigeria ;* [6]*Department of Soil Science, University of Nigeria, Nsukka 410001, Nigeria.*

**Abstract**

Sustainable agricultural rice production is realized by balanced application at farmers' fields of both: (i) varietal improvement through biotechnology, and (ii) the improvement of rice ecological environment through eco-technology. Compared to the biotechnological research and development, eco-technological research and development has been largely neglected in Sub Saharan Africa (SSA) during the last 40 years. Rice Green Revolution (GR) comprises three core technologies: (a) irrigation, (b) agrochemicals input, and (c) high-yielding varieties (HYV). Although all these three technologies have been available for the past 40 years, they have not been effective at farmers' fields in SSA. Thus, there has been a considerable paddy yield gap between African Research Institutions results (5-8 t $ha^{-1}$) and those of farmers (1-3 t $ha^{-1}$). However, during this period, three major components of GR technologies have been researched on and developed. Although they have been available at the experimental fields of various research institutions in Africa, these technologies have not been effectively adapted in African rice farmers' fields. Almost all institute-based technologies have not been scaled up to farmers' fields. Thus, the GR is yet to be realized. All scientific technologies have some limited operational conditions in the fields. The *sawah* ecotechnology is the prerequisite condition for applying the three GR technologies (Sawah hypothesis 1). The term "*sawah*" is of Indonesian origin. To control water in farmers' fields need *sawah* systems. If no *sawah* systems are available, farmers can not control water and majority of African farmers' fields will not be ready to accept most of the scientific technologies developed at research institutes like IITA and AfricaRice. Thus, in order to effectively apply these scientific technologies, farmers have to develop typical *sawah* or other similar alternatives which can conserve soil and control water. Essential components of such *sawah* development are: (i) demarcation by bunding based on topography, hydrology and soils, (ii) levelling and puddling to control and conserve soil and water, and (iii) water inlet to get water (through various irrigation facilities) and water outlet to drain excess water. These are the basic characteristics of *sawah* fields. *Sawah* eco-technolgy which can improve irrigation and fertilizer efficiency, will thus help to cope with water shortage and poor nutrient (especially N and P) supply. It can also neutralize acidity and/or alkalinity as well as improve micronutrient supply. With this, the improved HYV can

perform better and the GR in Africa can be realized. Thus for the three GR technologies to be successful, the *sawah* ecotechnology is a prerequisite. Lowland *sawah* can also sustain rice yield higher than 4t $ha^{-1}$ through macro-scale natural geological fertilization and other micro-scale mechanisms to enhance supply of various nutrients. For optimum results, appropriate lowlands must be selected, developed and soil and water managed properly. If such improved agronomic practices as System of Rice Intensification or others are further applied using the *sawah* systems, paddy yield can exceed 10t $ha^{-1}$. After continued long-term basic and action researches during 1986-2010, *sawah* research programs have finally established basic technology sets for the system. This is the "site specific personal irrigated *sawah* systems development and management by farmers' self-support efforts" (*sawah* eco-technology) in diverse inland valley agro-ecologies at forest and transitional zones in Ghana and at derived and core Savannah zones in Nigeria. Presently, the *sawah* ecotechnology has arrived at the stage of conducting large scale action research to scale up past successful results. This is the final stage of the road map to disseminating the *sawah* eco-technology in the whole of Ghana and Nigeria in order to realize rice GR in both countries. It is expected to extend to Togo and Benin as well as the entire SSA.

**Introduction**

In 1935, Dr. G. Inazuka, a breeder at Iwate Prefectural Experimental Station, Japan, successfully bred the Norin 10 variety of wheat. This was collected in 1948 by scientists under US-occupied forces in Japan. In 1953, the variety was transferred to Dr. N. Borlaug at Chapingo, Mexico. By 1957, Dr. Borlaug had used Norin 10 to quickly breed and release 14 high-yielding wheat varieties. This research was the start of the dramatically successful green revolution (GR) and the start of Consultative Group of Intgernational Agricultural Research (CG) centers in the 1960s-1970s (Evenson and Gollin 2003, Hesser 2006, Hardin 2008, Renkow and Byerlee 2011). Norin 10 was the first crop variety in which the characteristics of a semi-dwarf gene (sd1) were identified. We now know that all high-yielding varieties (HYV) of wheat, maize and rice have the same sd1 gene (Ashikali et al. 2002, Matsuoka 2004). Thus Dr. G. Inazuka is actually the "grandfather" of the GR.

Since the dramatic success in Latin America and Tropical Asia in 1960-1970s, similar variety-oriented research for GR has been intensively and extensively conducted in sub-Saharan Africa (SSA). Probably in response to the view that the failure to realize GR was due to the absence of appropriate varieties for the continent (Sanchez 2002). The Africa Rice Center innovated the new rice cultivar for Africa (NERICA). The NERICA technology has in deed shown to be very promising (FAO 2007). In 2005, the Millennium Village Project (MVP) was established in 14 hunger and poverty hotspots cutting across diverse agroecological zones in the region. This was in fulfilment of one of the recommendations in accordance with the Millennium Development Goals (MDGs) of the UN. In spite of all these interventions, the GR is yet to be realized in SSA. Hence, SSA remains the only region where population continues to grow while per capita agricultural production is stagnated, with cereal yields rarely exceeding 1 t $ha^{-1}$ (Hazell and Wood 2008). It is even more worrisome to note that despite the intensive variety-oriented research and wide technology dissemination, the path to successfully realising GR in SSA remains unclear (Otsuka 2006, Otsuka and Kalirajan 2006, Orr et al. 2008, Wopereis et al. 2008).

In 2007, the Alliance for Green Revolution in Africa (AGRA) began large-scale activities (Toenniessen et al. 2008). The government of Japan has committed strong support to increasing rice production in Africa through the establishment of the Coalition for African Rice Development (CARD 2008) based on the Fourth Tokyo International Conference on African Development (TICAD 4) held in May 2008 at Yokohama, Japan. Similar to the UN MVPs, AGRA and CARD have big scale activities for a GR. All of these world major organizations have hypothesized that the core technology to realizing a GR in Africa will be varietal improvements achieved by bio-technology, as was the case in tropical Asia 40 years ago. However, their advocacy for HYV is not without stressing some natural resources management (NRM) oriented modifications. Hence, although the central target of especially AGRA and CARD is varietal improvement, their programs include soil and water management aspects. A more realistic approach to sustainable agricultural production is by balanced application at farmers' field of both: (i) varietal improvement through biotechnology, and (ii) the improvement of rice ecological environment through eco-technology. It is our believe therefore that the core technology to contribute to GR in Africa is eco-technology and an example is the *sawah* eco-technology.

Compared to the biotechnological research and varietal improvement, eco-technological research and technology development have been largely neglected in SSA during the last 40 years. Although there is a research concept to improve natural resource management (NRM), no clear research concept to improve lowland soil and water condition exist in Africa. The *sawah* ecotechnology is such a missing concept to improve natural resources in majority of African rice farmers' fields. For over 25 years (1986-2010) now, we have been using various research funds to engage in basic and action researches in collaborations with Africa Rice Centre, IITA, JIRCAS-Japan, Ghana's Soil Research Institute (SRI) and Crops Research Institute(CRI), National Center for Agricultural Mechanization (NCAM), National Cereals Research Institute (NCRI), and University of Nigeria, Nsukka

(UNN) as well as University of Agriculture, Abeokuta and various other universities in Nigeria. So far our involvement in the on-going long-term research, has been able to verify the importance of water control through the *sawah* system. At farmers' level, our *sawah* research programs finally have establish basic technology sets of "site specific personal irrigated *sawah* systems development and management by farmers' self-support efforts"(hereinafter referred to as *sawah* ecoetchnology) in diverse inland valley agro-ecologies at forest and transitional zones in Ghana and derived and core Savanna zones in Nigeria. In 2011, the sawah team demonstrated *sawah* eco-technology successfuly on the huge flood plains in collaboration with Kebbi state Fadama III and ADP staff, Nigeria. One power tiller could develop 7 ha of the pump based irrigated sawah systems with over 7t ha$^{-1}$ of paddy yield during April to September (6 months).

The *Sawah* eco-technology has now arrived at the stage of conducting large scale action research to scale up past successful results. This will be the final stage of the road map to disseminating the *sawah* approach in the whole of Ghana and Nigeria. The ultimate aim is to realize rice GR in both countries and in the entire SSA.

***What is 'Sawah', Paddy and Irrigation?***

The English term, paddy, originated from Indonesia, and means rice plant or rice grain with husk. The term *sawah* is also of Indonesian origin, and refers to a bunded, puddled and leveled rice fields with water inlet and outlet to improve water control, especially control of flooding, water depth and movement, and thus soil fertility (Wakatsuki et al. 1998). Thus *sawah* ecotechnolgy can improve irrigation and fertilizer efficiency, and with the technology, improved varieties can perform better to realize GR in Africa. Suffice it to say that the *sawah* eco-technology is the prerequisite condition for the successful application of the three GR technologies. As shown in Figure 1, a *sawah* system is composed of *sawah* fields and irrigation/drainage facilities in a small inland valley watershed. The lowland *sawah* can also sustain rice yield higher than 4t ha$^{-1}$ through macro scale natural geological fertilization from upland and micro scale mechanisms to enhance various nutrient supply, if appropriate lowlands are selected, developed and soil and water managed properly.

Most of the paddy fields in Asian countries correspond to the definition of the term *sawah*. Therefore, the paddy fields are almost equivalent to *sawah* for Asian scientists. However in West Africa, the term paddy refers to just a rice field including upland rice fields. In order to avoid confusion and to stress the focal point to realizing the long-awaited rice GR through the improvement of rice ecological environment using eco-technology, the term *sawah* is used to describe the improved man-made rice-growing environment and the rice plant growing in it.

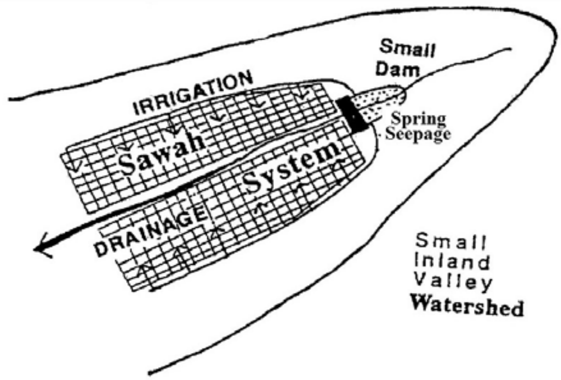



**Figure 1. Sawah system with irrigation and drainage facilities for control of water in an inland valley watershed**

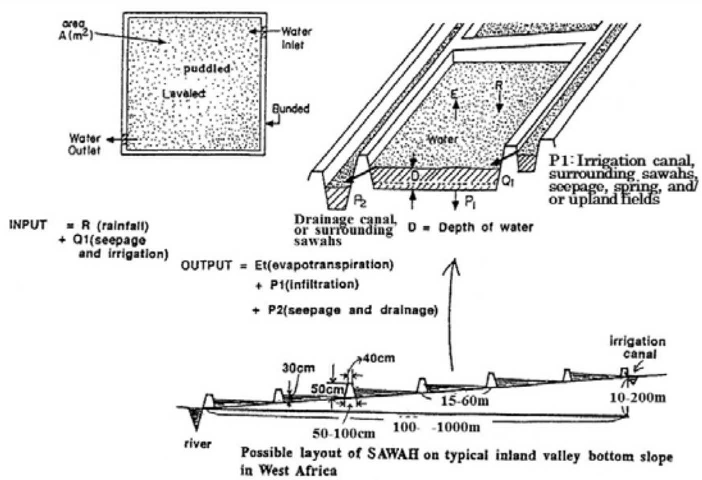



**Figure 2. Sawah: A leveled, bunded, and puddled rice field with inlets and outlet to control water**

Another frequent source of misunderstading in West Africa is the term irrigated rice. In Asia, the meaning of this term is clear, as *sawah* has been historically developed by local farmers using hundreds or even thousands of historical years, before the coming of irrigation projects recently (after 1970s) by Asian governments. However, since both irrigation and *sawah* are new and the concept of *sawah* has been lacking, there have been many irrigation systems without proper *sawah* development in West Africa and SSA.

In a well planned and developed *sawah* field, the water inlet and outlet should be installed at the bunds with gate connecting with irrigation and drainage (Figure 2, upper part). Proper knowlegde, especially of sloping pattern and hydrology, of the field is needed to do this. In an extensive watershed, the interval of bunding is guided by the slope (Figure 2, lower part). The aim should be to maintain an interval that would permit adequate levelling of the puddled soil for optimum water control.

***'Sawah' Hypothesis (I) for a Green Revolution in Sub-Saharan Africa***

There has been a considerable paddy yield gap between African Research Institution(5-8 t $ha^{-1}$) and those of farmers (1-3 t $ha^{-1}$) for the past 40 years. During this period, three major components of GR technologies, (improved seeds, fertilizers & other agrochemicals, and irrigation) have been researched on and developed. Although they have been available at the experimental fields of various research institutes in Africa, these technologies have not been effectively adapted in African rice farmers' fields. Almost all institute-based technologies have not been scaled up to farmers' fields. Thus, the GR is yet to be realized. The Google air photograph and the Figure 3 can explain the reason. All scientific technologies have some limited operational conditions in the fields. A very scientific requirement of the technology that calls for experience or skills acquired through training and practical field application is the demarcation of the field into basins using bunds. Good demarcation not only helps to control water and conserve soils but also encourages the expression of the beneficial physical and biochemical interactions going on either upland or lowland. As shown in the Google air photograph, necessity of fields' demarcation is not only on lowland but upland as well.

To control water in farmers' fields, 'sawah' systems are needed. Majority of African farmers' fields are not ready to accept most of the scientific technologies developed at research institutes like IITA and AfricaRice. 'Sawah' eco-technology is the prerequisite condition for applying the three Green Revolution technologies (ref: 'Sawah' hypothesis 1). To increase rice production, both "varietal improvement" through breeding studies using bio-technology and "improvement of ecological environments of farmers' fields through 'sawah' studies using eco-technologies are equally important. The two technologies are complementary to each other. Biology and ecology (environment) are the two basic components of agriculture. However, 'sawah' studies to improve farmers' ecological environments have been largely neglected in Africa. There is therefore the need to accelerate 'sawah' development in Africa.

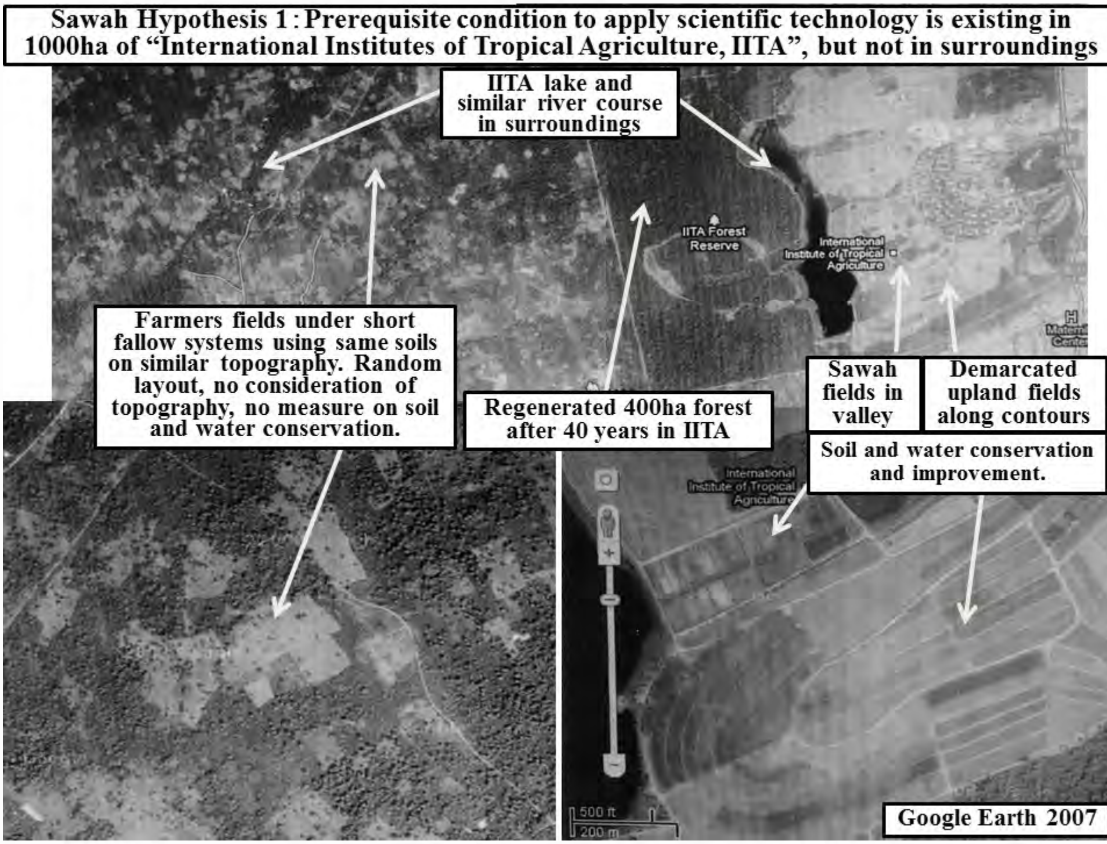



Fig. 3

The '*sawah*' hypothesis for realising GR in Africa is that farmers' '*sawah*' should come first. This paper explains why the core technology for GR in SSA is '*sawah*' eco-technology as outlined by Wakatsuki et al. 1998, Wakatsuki et al. 2001, Hirose and Wakatsuki 2002, Wakatsuki and Masunaga 2005, Wakatsuki et al. 2005 and 2009, Oladele et al. 2010, and Abe and Wakatsuki 2011 and illustrated in Figure 4. The paper also explains five key technologies necessary under the '*sawah*' approach to achieve a GR in SSA. The rice GR must include three core technologies: (i) irrigation, (ii) fertilizers and agrochemicals, and (iii) use of HYV. In order to apply these scientific technologies, farmers' fields must be developed into '*sawah*' or other similar alternatives typically in the lowlands that can conserve soil and control water. Essential components with regard to land development are (i) demarcation by bunding based on topography, hydrology, and soils, (ii) puddling and levelling to control and conserve soil and water, and (iii) water inlets to get water (using various irrigation facilities) and water out-lets to drain any excess water. These are the characteristics of '*sawah*' fields. For various social and historical reasons since the 1500s, these basic land and infrastructure developments to make the scientific technologies necessary for a green revolution possible have been disturbed in SSA (Hirose and Wakatsuki 2002).

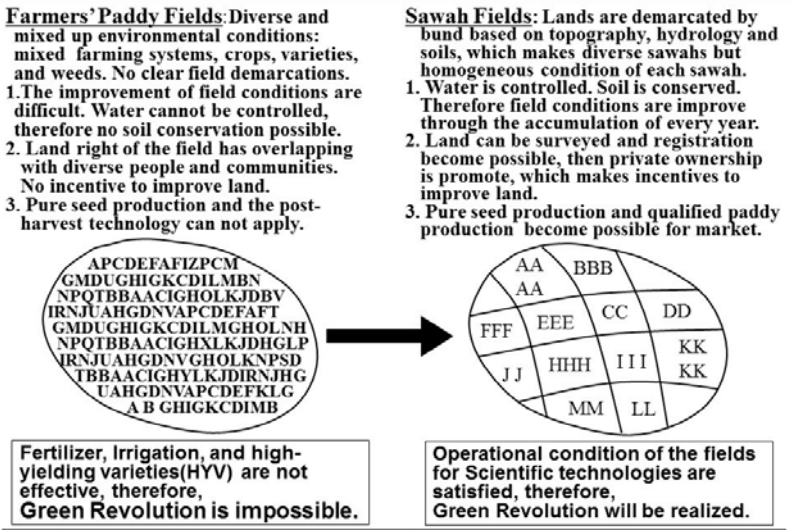



**Fig.4. Sawah hypothesis (1): Farmers' Sawah should come first to realize Green Revolution. Farmers fields have to be classified and demarcated ecotechnologically. Then scientific technology can be applied.**

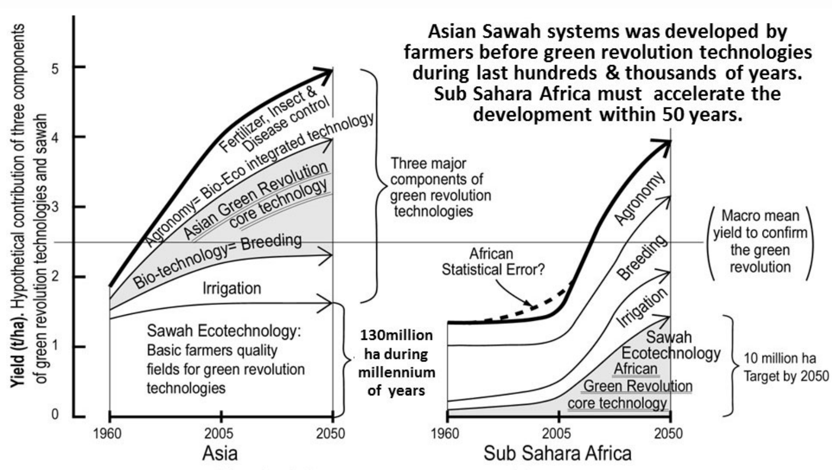



**Fig.5. Sawah hypothesis(1) for Africa Green Revolution:**
**Hypothetical contribution of three green revolution technologies & sawah system development during 1960-2050. Bold lines during 1960-2005 are mean rice yield by FAOSTAT (2006). Bold lines during 2005-2050 are the estimation by the authors.**

As shown in Figure 4, Asian 'sawah' systems were developed by farmers' self-support efforts before GR technologies were introduced. These are the basic infrastructures needed before applying High Yielding Varieties (HYV), Fertilizer and government assisted irrigation technologies. Thus Sub Saharan Africa has to accelerate the 'sawah' system development to realize GR through the provision of such structures.

### *'Sawah' Hypothesis (II) for Intensive long-term Sustainability and to combat global warming*

The upper part of Figure 5 illustrates the concept of watershed eco-technology or "Watershed Agro-forestry" (Wakatsuki and Masunaga 2005). The soils formed and the nutrients released during rock weathering and soil formation processes in upland areas are transported and deposited in lowland areas through geological fertilization processes. These processes include soil erosion and sedimentation, surface and ground water movement, as well as formation of colluviums. Ideal land-use patterns and landscape management practices will optimize the geological fertilization processes by ensuring optimum hydrology in a given watershed. Irrigation, surface, and subsurface water also contribute to increase in the supply of such nutrients as Si, Ca, Mg, K and $SO_4$. This contribution provides an ecological engineering basis for sustainability of intensive lowland '*sawah*'-based rice farming (Greenland 1997; Wakatsuki et al. 1998; Hirose and Wakatsuki 2002; Ofori et al. 2005; Wakatsuki and Masunaga 2005).

The lower half of Figure 6 shows the micro-scale mechanisms of the sustainability of the '*sawah*' system. The '*sawah*' system can be managed as a multi-functional constructed wetland. Submerged water can efficiently control weeds. Under submerged conditions, P availability is increased through the reduction of ferric iron. Both acid and alkaline soil pH are neutralized or mitigated by appropriate regulation of submergence. Hence, micronutrient availability is also increased. These mechanisms encourage not only the growth of rice plants but also of various aquatic algae and other aerobic and anaerobic microbes, which increase N fixation in the '*sawah*' systems through increases in photosynthesis. Hence the status of the '*sawah*' systems as functional wetlands. Puddling is important to encourage a collaboration of diverse microbes' consortia through various nanowire' interactions in the puddled soft '*sawah*' soils similar to marine sediments (Wakatsuki et al., 1998; Hirose and Wakatsuki, 2002; Kyuma, 2004; Wakatsuki et al., 2009; Nielsen et al., 2010).

Lowland '*sawah*' systems can sustainably produce paddy at approximately 2t $ha^{-1}$ without any chemical fertilizer application (Hirose and Wakatsuki 2002; Wakatsuki et al., 2009). Furthermore, lowland '*sawah*' systems can support rice cultivation continuously for decades or centuries without any fallow period. In contrast, upland slash and burn rice fields hardly ever sustain paddy yields in excess of 1 t $ha^{-1}$ without fertilizer. In addition to this lower yields; upland paddy fields require a fallow period to restore soil fertility, typically for 2 years of cultivation, 8 - 15 years of fallow may be required. This means that 1 ha of sustainable upland rice cultivation requires at least additional 5 ha of land. Therefore, sustainable upland paddy yield is actually not 1t $ha^{-1}$ but less than 0.2t $ha^{-1}$. In a'l, the sustainable productivity of '*sawah*'-based rice farming is more than 10 times higher than that of the upland slash and burn rice ('*Sawah*' Hypothesis II). We know this to be true based on a long history and experience (not experiments) of '*sawah*'-based rice farming in Asia, although no scientific or quantitative confirmation exists yet.

It is therefore important to determine sustainable yields quantitatively under SSA conditions. It is known that the development of 1 ha of lowland '*sawah*' field enables the conservation or regeneration of more than 10 ha of forest area. '*Sawah*' fields can, therefore, contribute to not only increased food production but also to forest conservation, which in turn enhances the sustainability of intensively used lowland '*sawah*' systems through nutrient cycling and geological fertilization processes (watershed agro-forestry or African SATO-YAMA system). SATO means villagers' habitat and YAMA means multipurpose forests managed by villagers. As a result of the sustainability of intensive lowland '*sawah*' systems, degraded upland fields can be converted to multipurpose forests. Thus as shown in Figure 6, '*sawah*' fields can contribute to the alleviation of global warming problems through the fixation of carbon in forest and '*sawah*' soils in ecologically sustainable ways (Hirose and Wakatsuki 2002, Wakatsuki et al. 2009).

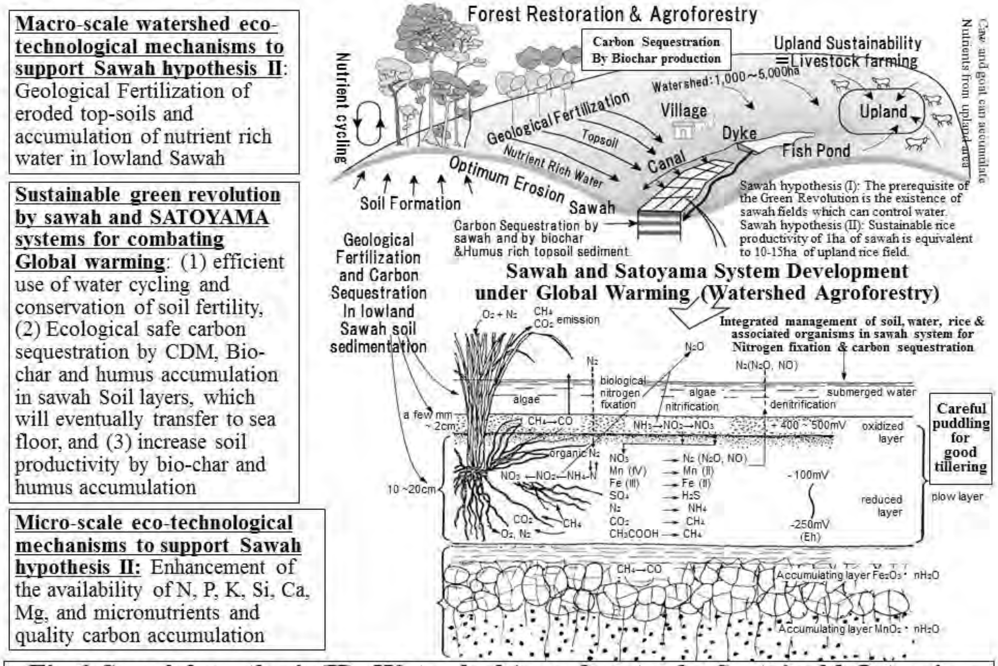



**Fig.6. Sawah hypothesis (II): Watershed Agro-forestry for Sustainable Intensive Rice cultivation and to combat global warming**

### *Comparison between biotechnology and 'sawah' eco-technology options for rice production.*

Figure 6 shows that the use of biotechnologically improved rice varieties alone cannot bring about the expected results in SSA. There is the need for '*sawah*'-based eco-technology to complement biotechnology in the region. Some of the different approaches of biotechnology and eco-technology to solving agronomic problems are itemised in Table 2. '*Sawah*' eco-technolgy can improve irrigation and fertilizer efficiency. Thus it can improve on water availability, poor nutrition especially for N and P supply, and neutralize acidity and alkalinity to improve micronutrient supply. With this, improved varieties can perform well to realize GR in Africa. Thus the '*sawah*' eco-technology is the prerequisite condition to apply the three GR technologies successfully. Lowland '*sawah*' can also sustain rice yield higher than 4t $ha^{-1}$ through macro scale natural geological fertilization from upland and micro scale mechanisms to enhance various nutrient supply, if appropriate lowlands are selected, developed, and soil and water managed properly.

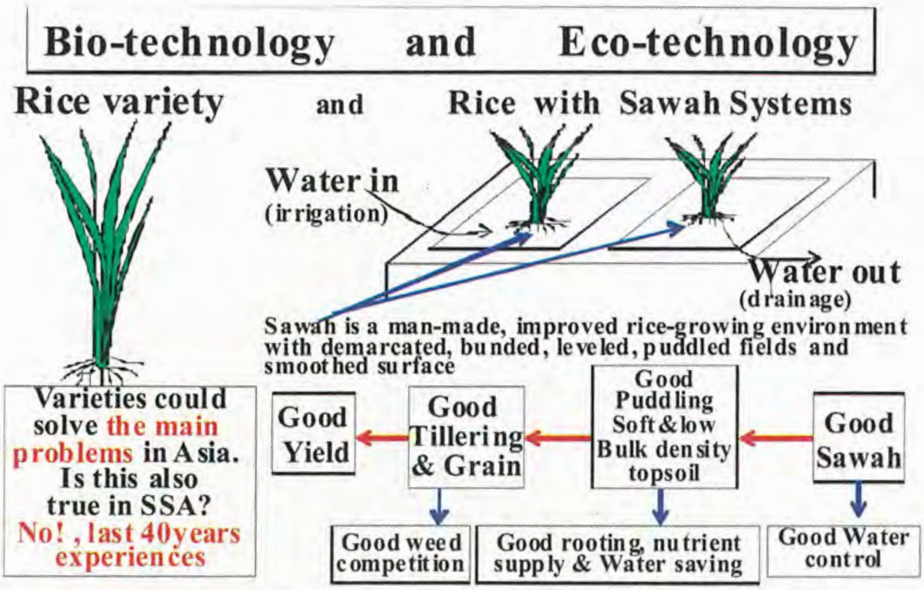



**Figure 7. Rice (variety) and environment (Sawah) improvement. Both Bio & Eco-technologies must be developed in good balance**

**Table 2.** Biotechnology and eco-technology differ in their approaches to solving agronomic problems.

| *Agronomic problem* | *Biotechnology* | *Eco-technology* |
|---|---|---|
| Water shortage | Genes for deep rooting, C4-nature and osmotic regulation | '*Sawah*'-based soil and water management: bunding, puddling, levelling and surface smoothening with various water harvesting and irrigation facilities |
| Poor nutrition, acidity and alkalinity | Genes for phosphate and micronutrient transportation | '*Sawah*'-based C and N fixation, increased P and micro - and macronutrient availability; geological fertilization; watershed agro forestry; and P-rich bird feculent |
| Weed control | Gene for rapid growth and enhanced weed competition. | '*Sawah*'-based weed management through proper levelling and smoothening, transplanting and water control; multi-factorial enhancement of tillering; duck and rice farming |
| Pest and disease control | Various genes for resistance | '*Sawah*'-based silica and other nutrients supply to enhance immune mechanisms of rice; mixed cropping |
| Food quality | Vitamin rice gene | '*Sawah*'-based nutrition control; fish, duck and rice in '*sawah*' systems |

In Table 3, the multi-functionality of 'sawah' systems in a watershed are summarised. Lowland '*sawah*' can produce about 2t $ha^{-1}$ of sustainable paddy yield without any chemical fertilizer application. However, in upland slash-and-burn rice fields, the yield without fertilizer rarely exceeds 1 t/ha, and fallow periods are needed to restore fertility, effectively reducing the sustainable yield to less than 0.2t $ha^{-1}$. Sustainable productivity of '*sawah*'-based rice farming is therefore more than 10 times higher than that of upland slash-and-burn rice. This '*Sawah*' hypothesis II has to be examined quantitatively under SSA conditions. Accordingly, the development of 1 ha of lowland '*sawah*' field enables the conservation or regeneration of more than 10 ha of upland forest area. '*Sawah*' fields can, therefore, contribute to not only increase food production but also to conserve of forest, which in turn enhances sustainability of intensive lowland '*sawah*' systems through nutrient cycling and geological fertilization processes (African SATOYAMA system). Furthermore, they contribute to the alleviation of global warming problems in the long run after solving food shortage problem through the fixation of carbon in forest and '*sawah*' soils in ecologically sustainable ways.

**Table 3:** Summary of multi-functionality of sawah systems

| | |
|---|---|
| *A* | ***Intensive, diverse and sustainable nature of productivity*** |
| i | Weed control by water and enhancement of nutrient supply |
| ii | Ecosystem nitrogen fixation (20-200kgN $ha^{-1}yr^{-1}$ fixed) |
| iii | Increases phosphate availability: concerted effect on N fixation |
| iv | pH neutralizing ecosystems: to increase micro-nutrient availability |
| v | Watershed geological fertilization: water, nutrients, topsoil from uplands |
| vi | Various sawah based farming systems options. |
| vii | Fish and rice; goose and 'sawah'; birds and 'sawah'; forest and 'sawah'. |
| *B* | ***To combact global warming and other environmental problems*** |
| i | Carbon sequestion through control of $O_2$ supply; methane emission under submerged conditions; nitrous oxide emission under aerobic rice |
| ii | Watershed agro-forestry, satoyama, to generate forest at upland |
| iii | Sawah systems as to control flooding & soil erosion, and to generate electricity |
| iv | Denitrification of nitrate polluted water |
| *C* | ***To create cultural landscape and social collaboration*** |
| i | Terraced sawah systems as beautiful cultural landscape |
| ii | Fare water distribution systems for collaboration and fare society |

## Conclusions

This paper has shown the concept of watershed eco-technology and watershed agro-forestry. The soils formed and nutrients released during rock weathering and soil formation processes in upland are accumulated in lowland through geological fertilization processes, such as soil erosion and sedimentation as well as surface and ground water movements or colluvial processes. The optimum land use pattern and landscape management practices optimize the geological fertilization processes through the control of optimum hydrology. Irrigation, surface and subsurface water also contribute to the increase in supply of nutrients, such as Si, Ca, Mg, K and $SO_4$. This is the ecological engineering basis for sustainability of intensive lowland '*sawah*'-based rice farming. The '*sawah*' system is also characterized by micro-scale mechanisms which help to ensure sustainability of the system under intensive rice production. The '*sawah*' system can be managed as multi-functional constructed wetland. Submerged water can control weeds. Under submerged conditions, phosphorus availability is increased through the reduction of ferric iron while both acid and alkaline soil conditions are neutralized or mitigated. Hence, micronutrients availability is also increased. These mechanisms promote not only rice growth but also the growth of various aquatic algae and other aerobic and anaerobic microbes, which increase N fixation in the system through increase in photosynthesis. This is the basis for referring to the '*sawah*' systems as functional wetlands. Puddling softens the soil and this is needed to encourage collaboration of diverse microbes' consortia through the various nanowire' interactions in '*sawah*' soils.

## References

Abe S and Wakatsuki T. 2011. '*Sawah*' Eco-technology Triggers Rice Green Revolution in Sub-Saharan Africa. *Outlook on Agric* Vol 40, No 3: 221-227

Agrawal GK, Takeda S, Abe K, Miyano A, Hirochika H, Kitano H, Ashikali M and Matsuoka M. 2004. An Overview of Gibberellin Metabolism Enzyme Gene and Their Related Mutants in Rice. *Plant Physiology* 134: 1642-1653

Ashikali M, Sasaki A, Ueguchi-Tanaka M, Itoh H, Nishimura A, Datta S, Ishiyama K, Saito T, Kobayashi M, Khush SD, Kitano H and Matsuoka M. 2002. Loss of function of a Rice Gibberellin Biosynthetics Gene, GA20 oxidase (GA200x-2), Led to the Rice 'Green Revolution'. *Breeding Sci.* 52: 143-150

Evenson RE and Gollin D. 2003. Assessing the impact of the green revolution, 1960 to 2000. *Science* 300: 758-762

FAO. 2007. Rice situation update as of 31 March 2007. FAO Rice Market Monitor, Vol. X, Issue No. 1. Food and Agricultural Organization of the United Nations. Available at: http://www.fao.org/es/esc/en/index.html

Greenland DJ. 1997. *Sustainability of Rice Farming*, CAB Int'l, U.K. and IRRI, Los Banos, 273pp

Hardin LS. 2008. Meeting that changed the world, Bellagio 1969: The green revolution, *Nature* 455: 470-471

Hazell P and Wood S. 2008. Drivers of change in global agriculture. Philos. Trans. R. Soc Lond, B. Biol Sci 363: 495-515

Hesser L. 2006. *The man who fed the world, Nobel peace prize laureate Norman Borlaug and his battle to end world hunger.* Durban house Publishing Company. Dallas, 263p, ISBN1-930754-90-6

Hirose H and Wakatsuki T. 2002. *Restoration of Inland Valley Ecosystems in West Africa.* Nourin Tokei Kyoukai, Tokyo. 600 pp

Kyuma K. 2004. *Paddy Soil Science,* Kyoto University Press, Kyoto, 280 pp

Nielsen LP, Risgaard-Petersen N, Fossing H, Christensen PB and Sayama M. 2010. Electric currents couple spatially separated biogeochemical processes in marine sediment. *Nature* Vol. 463 | 25 February 2010 | doi:10.1038/nature08790

Ofori J, Hisatomi Y, Kamidouzono A, Masunaga T, and Wakatsuki T. 2005. Performance of Rice Cultivars in Various '*Sawah*' Ecosystems Developed in Inland Valleys, Ashanti Region, Ghana. *Soil Sci. Plant Nutr.* 51: 469-476

Oladele OI, Bam RK, Buri MM and Wakatsuki T. 2010. Missing prerequisite for Green Revolution in Africa: Lessons and the challenges of '*Sawah*' rice eco-technology development and dissemination in Nigeria and Ghana. *J. Food Agric Environ* 8: 1014-1018

Orr S, Sumberg J, Erenstein O and Oswald A. 2008. Funding international agricultural research and the need to be noticed: A case study of NERICA rice. *Outlook on Agric* 37: 159-168

Otsuka K and Kalirajan KP. 2006. Rice green revolution in Asia and its transferability to Africa: An introduction. *Dev Econs* 44:107-122

Otsuka K. 2006. Why can't we transform traditional agriculture in sub-Saharan Africa? *Review of Agric Econs* 28:332-337

Renkow M and Byerlee D. 2011. The impact of CHIR research: A review of recent evidence. *Food policy* (in press)

Sanchez P. 2002. Soil fertility and hunger in Africa. Science 295: 2019-2020

Toenniessen G, Adesina A and DeVries J. 2008. Building an Alliance for a Green Revolution in Africa, Ann. *New York Academy of Sci* 1136:233-242

Wakatsuki T and Masuanga T. 2005. Ecological Engineering for Sustainable Food Production and the Restoration of Degraded Watersheds in Tropics of low pH Soils: Focus on West Africa. *Soil Sci. Plant Nutr.* 51:629-636

Wakatsuki T, Buri MM and Oladele OI. 2009. West African green revolution by '*sawah*' eco-technology and the creation of African Satoyama systems, *http://www.humanosphere.cseas.kyoto-u.ac.jp/article.php/workingpaper61*

Wakatsuki T, Buri MM, and Fashola OO. 2005. Ecological Engineering for sustainable rice production and the restoration of degraded watersheds in West Africa. In: *Rice is Life: Scientific Perspectives for the 21st Century.* Toriyama, K, Heong, KL and Hardey B. (eds), pp 363-366, IRRI, JIRCAS, NARO, NIAS, NIAES, NIRE, APO, MAFF, Tsukuba, Japan

Wakatsuki T, Buri MM, Obalum SE, Bam R, Oladele OI, Ademiluyi SY and Azogu II. 2011. Farmers' personal irrigated '*sawah*' systems to realize the green revolution and Africa's rice potential, Paper presented at 1st International Conference on Rice for Food, Market, and Development (rice-Africa), Abuja, Nigeria March 3-5, 2011

Wakatsuki T, Otoo E, Andah WEI, Cobbina J, Buri MM and Kubota D. (Eds). 2001. *Integrated Watershed Management of Inland Valley in Ghana and West Africa: Eco-technology Approach*, Final Report on JICA/CRI joint study project, CRI, Kumasi, Ghana and JICA, Tokyo, 337pp

Wakatsuki T, Shinmura Y, Otoo E and Olaniyan GO. 1998. African based '*sawah*' systems for the integrated watershed management of small inland valleys in West Africa. *In FAO Water Report No. 17. Institutional and Technical Options in the Development and Management of Small Scale Irrigation.* Rome, pp 45-60

Wopereis MCS, Diagne A, Rodenburg J, Sie M and Somado EA. 2008. Why NERICA is a successful innovation for African farmers: A response to Orr et al from the Africa Rice Center. *Outlook on Agric* 37:169-176

# An Overview of the "Sawah" Project and Its Implications for Future Rice Production in Ghana.

Buri M. M.[1], Issaka R. N.[1] and Wakatsuki T[2].

[1]CSIR – Soil Research Institute, Academy Post office, Kwadaso – Kumasi, Ghana
[2]Faculty of Agriculture, Kinki University, Nara 8505, Japan
Email: moro_buri@yahoo.com

*Abstract*

While farmers need improved technologies to increase production, such technologies must be easy to adopt and environmentally friendly for sustainability. Effective nutrient and water management in addition to suitable land preparation options are key factors for effective and sustainable utilization of rice growing ecosystems in Ghana. It was for these reasons that the "Sawah" system of rice production was developed and introduced to farmers. Since its introduction, not only have rice grain yield increased significantly (current yields: > 6.0 t $ha^{-1}$ as against < 2.0 t $ha^{-1}$ under traditional system) and could go higher with improved management, income has also correspondingly and significantly increased, thus creating an avenue for employment. In addition, it has been observed that the system supports the use of local resources to improve soil productivity. Water management, a major challenge to rice cultivation, has also significantly improved. The system is also environmentally friendly as soil movement is very minimal and land degradation almost non-existent. Since its inception, over 2000 farmers have been introduced to improved soil and water management practices either directly or indirectly with over 30 power tillers made available to farmers for land development. However, obstacles to the progressive adoption of this technology include lack of spare parts for the main machinery (power tiller - two wheel tractor) used for land preparation. Even though a few farmers have acquired these machines either individually or in groups, constant break downs accompanied by lack of spare parts poses a major challenge. Obnoxious land tenure systems which do not encourage effective planning and investment in land management is another disincentive. The initial construction of "Sawah" fields requires a sizeable commitment of resources and farmers will therefore require longer periods of guarantee over their farm lands. Ghana can increase paddy yield of between four to five fold when the "Sawah" technology is scaled out through effective policy interventions. In addition, the "Sawah" system relies more on intensification rather than extensification. While this will result in significant increases in yield per unit area, it will further reduce the amount of land cultivated, and hence a reduction in environmental degradation currently associated and aggravated by extensive cultivation.

**Keywords:** environment, rice paddy yields, revenue generation, rural, employment, sawah system, sustainability,

**Introduction:**

In Ghana naturally occurring rice growing environments mostly composed of inland valleys and river flood plains make up over one million hectors of lands. However, current rice production levels are said to be around 30% to 40% of total national requirements. Major causes for low productivity may be traced to lack of proper management of our soil resources and declining soil productivity. Several reports indicate the low fertility status of most rice growing environments in Ghana (Buri et al, 2008; 2009; 2010; 2011) and the West African sub-region (Abe et al, 2010; Buri et al, 1998; Issaka et al, 1995) as a whole. While for some time now too much emphasis has been placed on bio-technology leading to the development of improved rice varieties with higher input requirements, very little seem to have been done towards improving the environment (eco-technology) in which these improved rice varieties are grown. Hence the yield gap between real and potential continues to widen unless this problem is addressed. It has therefore been suggested that, to realize the green revolution in Africa, more and detailed research on natural resource management should be seriously and vigorously pursued (Wakatsuki et al, 2003, 2004, 2011a 2011b). In this light, the designing and implementation of comprehensive and integrated soil management programs that will not only improve and maintain soil fertility, arrest further environmental degradation but also make maximum use of limited water are necessary. The sawah system attempts to provide solutions to the outlined challenges facing rice cultivation in the country.

**Materials and Methods**

Following the introduction of the "Sawah" system of rice production to selected communities, mostly within the Mankran watershed (Figure 1), field developmental activities, productivity levels, and challenges facing farmers under "the improved system were monitored over the period across locations. The watershed covers an area of over 11000 ha. The project adopted two approaches: (i) developmental approach (technology transfer) where major activities conducted were farmer organization and on-the-job training (field development) for both farmers and extension staff of the Ministry of Food and Agriculture, monitoring of paddy yields of farmers' groups and estimation of revenue generated. (ii) Research and capacity building which involved the conduction of field experiments in the areas of soil, water, nutrient and environment, to improve upon the efficiency of the system and training for all levels of students, both local and international were conducted.

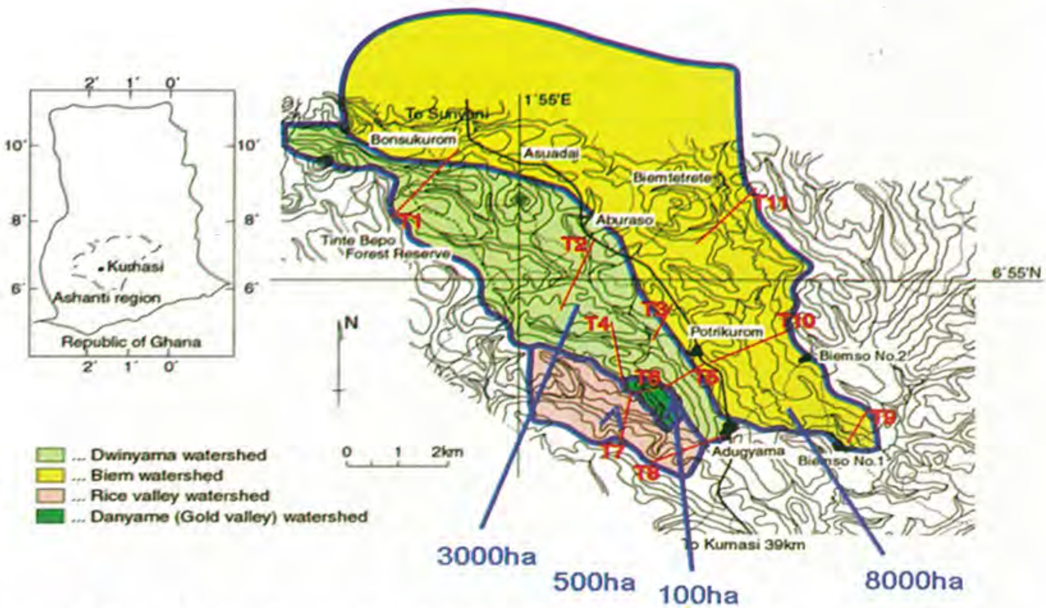



**Figure 1**. Map of Mankranso Watershed showing the Project Area

## Results and Discussion

*(a) Crop yields:*

Since its introduction, farmers rice grain yields have increased significantly. "Sawah" rice farmers' now record almost 6.0 t ha$^{-1}$ paddy as against less than 2.0 t ha$^{-1}$ normally recorded under the traditional system (Figure 2). Mean paddy grain yield, with the introduction of "Sawah" started at 4.0 t ha$^{-1}$ rising to a current level of almost 6.0 t ha$^{-1}$ and could go higher with improved management. With such higher yields, the presence of guaranteed markets can serve as motivation for more farmers to go into rice production under the "Sawah" system. In addition income has also correspondingly and significantly increased (Table 4), thus creating an avenue for rural employment and increased food production with guaranteed food security.

*(b) Improved fertilizer-use efficiency*

Fertilizer management has been a major challenge for farmers over the years. Farmers tend to gain very little as larger amounts of applied fertilizer are not utilized by the intended crop (low-use-efficiency). Under "Sawah" systems, crop responds to applied fertilizer has been very great, an indication of a significant increase in the utilization of added nutrients. Buri et al (2007) amongst others reported of significant responses to mineral fertilizer application (particularly the macro-nutrient elements – N, P, K) from rice under the "Sawah" systems (Table 1) in selected valleys in southern Ghana, and therefore recommended mineral fertilizer addition for effective and sustainable nutrient management. Such significant responses to mineral fertilizer additions is reflected in higher paddy yields as shown in Figure 2.

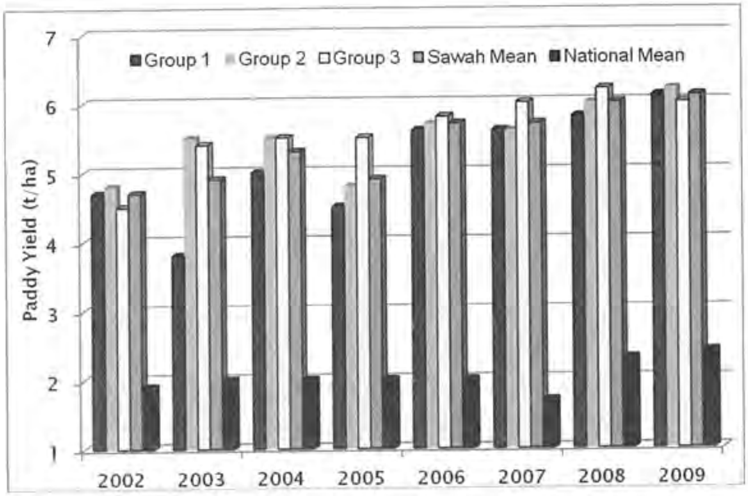



**Figure 2.** Comparison of yield (t $ha^{-1}$) performance of "Sawah" farmers with National (Ghana) mean

**Table 1.** Response of paddy grain yield (t $ha^{-1}$) to mineral fertilizer under the "Sawah" system

| | Adugyama | | Biemso | |
|---|---|---|---|---|
| ($N-P_2O_5-K_2O$) Kg $ha^{-1}$ | 2004 | 2005 | 2004 | 2005 |
| 0 - 0- 0 | 0.96 | 1.06 | 0.97 | 1.10 |
| 0 - 90 - 90 | 1.29 | 1.48 | 1.39 | 1.47 |
| 90 - 0 - 90 | 2.03 | 2.08 | 1.99 | 2.04 |
| 90 - 90 - 0 | 3.09 | 2.31 | 2.75 | 2.53 |
| 90 -90 - 90 | 6.84 | 6.89 | 7.07 | 7.11 |
| SE | 1.232 | 1.246 | 1.287 | 1.292 |

Source - Buri et al, 2007

*(c) Integrated nutrient management*

The affordability of mineral fertilizers by farmers is very limited. Most rural farmers cannot afford the ever rising cost of mineral fertilizers. In the light of increasing mineral fertilizer prices (farmers cannot afford to buy) and relative abundance of local amendments, an integrated approach for soil fertility management is encouraged under the "Sawah" system. This becomes easier and sustainable as farmers are trained to manage "Sawah" operation by themselves through on-the-job training and use of several locally available resources. There are several soil amendments which are common and available in most rice growing communities. As such, the use of such materials to compliment mineral fertilization has been recommended for most farmers. Depending on source and age, most soil amendments such as poultry droppings and cattle manure have been reported (Buri et al, 2008) to give significantly higher grain yields (Table 2) when used in combination with mineral fertilizers or solely. The promotion of the use of such materials will not only help increase productivity but is also sustainable and ecologically friendly. These are materials that also provide both physical and chemical support to our already fragile and depleted soils.

**Table 2.** Effect of integrated nutrient management under the "Sawah" system

| | Paddy Grain Yield (t $ha^{-1}$) | | |
|---|---|---|---|
| Treatments | Potrikrom | Beimso I | Biemso II |
| Control (no manure, no mineral fertilizer) | 1.68 | 1.59 | 1.50 |
| $N-P_2O_5-K_2O$ (120-90-90) Kg $ha^{-1}$ | 6.77 | 8.37 | 4.03 |
| $N-P_2O_5-K_2O$ (90-60-60) Kg $ha^{-1}$ | 6.57 | 7.09 | 3.90 |
| Poultry Manure (7.0t ha-1) | 5.96 | 6.36 | 3.82 |
| Poultry Manure (3.5 t ha-) + Mineral fertilizer (45-30-30) | 6.25 | 7.30 | 4.15 |
| Cattle Manure (7.0 t ha-1) | 4.54 | 6.25 | 3.05 |
| Cattle manure (3.5 t ha-) + Mineral fertilizer (45-30-30) | 4.86 | 6.49 | 3.72 |
| LSD (0.05) | 0.99 | 2.14 | 0.84 |
| Mean (site) | 5.23 | 6.09 | 3.58 |
| LSD (site) | | 0.52 | |

Source - Buri et al, 2008

*(d) Improved soil and water management*

Under the "Sawah" system, there is improved soil and water management through the construction of bunds to retain water and puddling and levelling of the soil to enhance easy water distribution. Water management under the sawah system implores the use of local resources. Water management structures are designed based on existing conditions within the rice growing environment and varies across locations. Issaka et al. (2008) reported that, rice grain yields across varieties significantly increased with improved soil and water management. Paddy grain yields increased in the order: farmers practice < bunded only < bunded and puddle < bunded, puddle and levelled rice fields (Table 3). Luck of proper soil and water management has been a major challenge to rice production across all agro-ecological zones in the country. The introduction of such technologies such as "Sawah" will significantly help to address such challenges. Water management structures under the sawah system can be modified to suit any ecology or prevailing conditions. Thus with significant improvement in water management under the sawah system, a solution has been found to one of the major challeges facing rice cultivation in the country.

**Table 3.** Rice paddy yield (t $ha^{-1}$) response to improved water management under the "Sawah" system

| Management/Rice variety | Bouake. 189 | Jusmine. 85 | Sikamo | Wita 7 | Mean |
|---|---|---|---|---|---|
| Year 1 | | | | | |
| Farmers practice (no water control) | 3.9 | 3.8 | 3.2 | 3.3 | 3.6 |
| Only bunded | 5.1 | 4.9 | 5.1 | 5.3 | 5.1 |
| Bunded and puddled | 6.8 | 5.5 | 6.5 | 6.2 | 6.3 |
| Bunded, puddled and levelled | 8.2 | 6.5 | 7.8 | 7.6 | 7.5 |
| Mean | 6.0 | 5.2 | 5.7 | 5.6 | |
| Year 2 | | | | | |
| Farmers practice (no water control) | 3.5 | 3.7 | 2.2 | 3.3 | 3.2 |
| Only bunded | 4.2 | 4.0 | 3.2 | 4.5 | 4.0 |
| Bunded and puddled | 4.8 | 4.5 | 4.3 | 4.9 | 4.6 |
| Bunded, puddled and levelled | 6.2 | 5.5 | 5.6 | 5.4 | 5.7 |
| Mean | 4.7 | 4.4 | 3.8 | 4.5 | |
| SE for each year | 1.12 | | | | |

Source – Issaka et al, 2008

*(d) Revenue Generation*

The ultimate aim of every farmer is to produce enough for home consumption and to generate enough revenue to help address other challenges. With significant increases in grain yield under the "Sawah" systems, not only are farmers able to produce enough for family consumption, but are able to make extra money from rice, to cater for other family needs. Among groups of "Sawah" rice farmers, Buri et al reported of net revenue (Table 4) ranging from US $1284 to US $1547 per hector of land. With improved yields under the "Sawah" systems, local rice cultivation can therefore serve as a major source for revenue generation and rural employment under effective and efficient management system. The realization of much revenue from rice cultivation under the sawah system can significantly lead to higher total production and possibly a significant reduction in rice imports.

Table 4. Income generated per unit area (1 ha) under the "Sawah" system (2004)

| Farmer-group | Paddy Yield (kg) | Gross Revenue (US $) | Production Cost (US $) | Net Revenue (US $) |
|---|---|---|---|---|
| Group 1 | 4334 | 1712 | 428 | 1284 |
| Group 2 | 4675 | 1847 | 350 | 1497 |
| Group 3 | 4736 | 1871 | 324 | 1547 |
| Group 4 | 4675 | 1847 | 349 | 1498 |
| Mean | 4605 | 1819 | 363 | 1456 |

Source - Buri et al, 2011

*(d) Coverage:*

The transfer of any technology to end users is very crucial and can influence its rate of adoption. The on-the-job training approach was adopted for the transfer of the sawah system. Currently, over 1500 farmers have been covered by the project either directly or indirectly. Over 100 hectors of lowlands have been covered with over 30 power tillers put into the fields for the on-the-job training and farmer to farmer training. About six farmers have been intensively trained and currently serve as leading famers under the farmer to farmer training, which is on-going.

*(e) Challenges:*

Mechanization of rice production activities is very necessary if higher production and productivity, including good quality material are to be achieved. As such the use of simple machinery is encouraged under the "Sawah" system particularly for land preparation. Major machinery used for land preparation activities is basically the power tiller (two wheel tractor). However, obstacles to the progressive adoption of this technology which also facilitates the rate of adoption include lack of spare parts and sometimes the availability of the machine itself on the market. Even though a few farmers have acquired these machines either individually or in groups, constant break downs accompanied by lack of spare parts poses a major challenge. Obnoxious land tenure systems which do not encourage effective planning and investment in land management is another disincentive as farmer's need minimum guarantee over land before they can invest their resources. The initial construction of "Sawah" fields is quite labour intensive and requires a sizeable commitment of resources. Farmers will therefore require longer land lease periods before committing such resources in the development of their rice fields.

**Conclusions:**

There is increased and improved nutrient utilization under the "Sawah" system with minimum environmental effects (environmentally friendly). The system has shown to be more productive with increased grain yields, increased income, rural employment opportunities and enhances food security. With the current national mean rice paddy yield of less than 2 t $ha^{-1}$, Ghana can increase paddy yield of over 300% when the "Sawah" technology is widely accepted and adopted. Adoption of the technology can be accelerated through effective policy interventions. Yields can go higher when certain challenges such as spare parts, land tenure and poor post harvest practices are improved. In addition, the "Sawah" system relies on intensification rather than extensification. While this will result in significant increases in yield per unit area, it will further reduce the amount of land cultivated, and hence a reduction in environmental degradation currently associated and aggravated by extensive crop cultivation.

**Recommendations.**

To make a national impact, the systems needs to be introduced to rice farmers across all ago-ecological zones where rice is cultivated (scaling out), which could be through policy, legislature or otherwise. There may also be the need to relook at the current land tenure systems, which can be modernize to make farming more attractive to potential farmers. Current land tenure systems in most parts of the country are a disincentive, to particularly rice farmers. The ministry of food and agriculture could facilitate private sector participation in the import of the necessary machinery and adequate spare parts, as mechanization of rice production under the systems will significantly result in increased production and good quality rice to compete favourably with imported rice which is currently cheaper and abundant in Ghanaian markets.

**References:**

Abe S. S, Buri M. M., Issaka R. N., Kiepe P. and Wakatsuki T. (2010). Soil Fertility Potential for Rice Production in West African Lowlands. JARQ, 44 (4), 343-355.

Buri M. M., Issaka R. N., Wakatsuki T and Kawano N. (2011): Improving the productivity of lowland soils for rice cultivation in Ghana: The role of the "Sawah" system. *Journal of Soil Sci. and Environmental Management.* Vol.2 (10), pp. 304-310

Buri M.M., Issaka R.N., Fujii H and Wakatsuki T (2010) Comparison of soil nutrient status of some rice growing environments in the major agro-ecological zones of Ghana. *Journal of Food, Agriculture & Environment. Vol. 8 (1):384-388*

Buri M. M., Fujii H and Issaka R.N. (2009) Preliminary fertility assessment of lowland soils of selected watersheds within the Savannah and Forest Agro-ecological zones of Ghana. Paper presented at the International workshop on Sustainable Development and Dissemination of Lowland Rice and Paddy Fields in Inland Valleys of West Africa, held from 24 – 25th February, 2009 at M. Plaza Hotel, Accra, Ghana.

Buri M. M., Issaka R. N. and Wakatsuki T. (2008): Reducing Rural Poverty through Improved and Sustainable rice production technologies: A case study of the "Sawah" system in the Ahafo Ano South district in Ghana. Paper presented at the International Conference on "Sustainable Agriculture for Food, Energy and Industry" held from 2-6th July, 2008 at Sapporo University, Hokkaido, Japan.

Buri M. M. and Fujii H. (2008). Soil Fertility Assessment of lowlands within the Mankran Watershed in the Ashanti region of Ghana for rice production. Paper presented at the International workshop held at the International Water Management Institute (IWMI), West Africa Office, Accra, Ghana. 2nd, June 2008

Buri M. M. Oppong J. Tetteh F. M. and Aidoo E. (2008). Soil Fertility Survey of Selected Lowlands within the Mankran Watershed in the Ashanti region of Ghana. CSIR – Soil Research Institute Technical Report No. 275

Buri M. M., Aidoo E. and Fujii H. (2008). Soil Fertility Survey of Selected Lowlands within the Jolo Kwaha Watershed near Tamale in the Northern region of Ghana. CSIR – Soil Research Institute Technical Report No. 279

Buri M. M., Issaka R. N and Wakatsuki T (2007): Determining Optimum rates of Mineral fertilizers for economic rice grain yields under the "Sawah" system in Ghana. *West African Journal of Applied Ecology. Vol.* 12. 19-31

Buri M. M. Issaka R. N. Wakatsuki T. and Otoo E. *(2004):* Soil organic amendments and mineral fertilizers: Options for sustainable lowland rice production in the forest agro-ecology of Ghana. *Agric. & Food Sci. Jour. of Ghana. Vol.* 3: 237-248

Buri M. M., Ishida F., Kubota D., Masunaga T., Wakatsuki T (1998); Soils of Flood plains of West Africa: General Fertility Status. Soil Science and Plant Nutrition. Japan 45 (1) 37-50

Issaka R. N. Buri M. M. and Wakatsuki T. (2011): Technology transfer for increasing and sustaining rice production in the Inland valleys: Adoption of the "Sawah" system. Paper presented at the 1st International conference on rice for food, market and development (rice-Africa), Abuja, Nigeria. March 3-5, 2011

Issaka R. N., Buri M. M. and Wakatsuki T. (2008). Effect of soil and water management practices on the growth and yield of rice in the forest agro-ecology of Ghana. *Journal of Food, Agriculture & Environment.* Vol. 7 (1): 214 - 218

Issaka, R. N., Masunaga, T., Kosaki, T. and Wakatsuki, T. (1996): Soils of Inland Valleys of West Africa: General Fertility Parameters. Soil Sci. Plant Nutr., 42. 71-80

Wakatsuki T., Buri M. M. Bam R. Aemiluyi S. Y, Ozogu I. I., Oladele O. O. and Igwe C. A. (2011). Multi-Functionality of "Sawah" Eco-technology: Why "sawah"-based rice farming is critical for Africa's green revolution. Paper presented at the 1st International workshop on "Sawah" eco-technology and rice farming in sub-Saharan Africa, held at Golden Tulip hotel, Kumasi, Ghana. November 22 – 24, 2011.

Wakatsuki T, Buri M. M., Obalum S.E., R. Bam, Oladele O. I., Ademuliyi S. e and Azogu I. I. (2011): Farmers personnal irrigated sawah systems to realize the green revolution and Africa's rice potential. Paper presented at the 1st International conference on rice for food, market and development (rice-Africa), Abuja, Nigeria. March 3-5, 2011.

Wakatsuki T. Buri M. M. and Fashola O. O. (2004): Ecological Engineering for Sustainable Rice production and the restoration of degraded watersheds in West Africa. World Rice Research, 2004, IRRI, 363-366

Wakatsuki T., Buri M. M. and Fashola O.O. (2003). Restoration of degraded inland valley watersheds in West Africa by sustainable "sawah" development. Paper presented at the International Conference on "Managing Soils for Food Security, Human Health and the Environment: Emerging Strategies for Poverty Alleviation." Accra, Ghana. 27th July – August 2nd 2003.

# Nigerian Policy on Agricultural Mechanization and Lowland Development: SERIF Achievement Strategy

Ademiuyi Y.S[1], Azogu I.I[1], Dada-Joel O.T[1] and T. Wakatsuki[2]

[1] *National Centre for Agricultural Mechanization, (NCAM), P.M.B 1525, Ilorin, Nigeria.*
[2] *Department of Ecological Engineering, Faculty of Agriculture, Kinki University, Nara, Japan. e-mail:*segunncam@yahoo.com

**Abstract**

It is a statement of fact that increased food and fibre production is a key issue facing developing countries, especially in the African continent. The main reason being that agricultural growth rate in these countries seriously lags behind their ever increasing population. In addition, there are various natural as well as institutional constraints which militate against rapid growth in the agricultural sector. Notably among these are climatic conditions, inadequate and untimely supply of inputs, limited funds and poor technological framework. These issues need to be seriously addressed if the trend must be reversed in the new millennium. Realizing that self sufficiency in food and fibre production is a major index for assessing a nation's developmental effort, policy makers were convinced that modernization of Nigerian agriculture through introduction and development of *need-based, home grown* agricultural mechanization technologies was the only way out of the log-jam of hunger and want. It was on this premise that NCAM was established in 1974 following the acceptance of the report of a team of experts set up by the Federal Government to advise her on the possible establishment of an agricultural mechanization institution based on its perceived roles elsewhere. This paper presents the Nigerian government policy on agricultural mechanization, lowland or river basin development as well as rice development strategies and policies and also provides ways of harmonizing all these policies and strategies for the speedy realization of sawah Eco-technology for Rice Farming (SERIF) in Nigeria.

**Keywords**: lowland, mechanization, policy, SERIF

## Introduction

In Nigeria, agriculture has remained the largest sector of the economy. It generates employment for about 70% of the population and contributes about 40% to the Gross Domestic Product (GDP) with crops accounting for 80%, livestock (13%), forestry (3%) and fishery (4%) as stated in the Nigeria National Report (2006). It plays significant roles in the nation's economic development. These roles include: (i) contribution to the country's gross domestic product, (ii) source of income and decent living for a large proportion of the population, (iii) provision of adequate

food for the people, (iv) supply of raw materials required by the industrial sector, (v) generation of foreign exchange through export, and (vi) provision of employment opportunities for the teeming population.
Nigeria has a land area of 98.3m hectares. At present about 34m hectares (48%) are under cultivation. Under the 1999 Constitution, responsibility for agricultural and rural development is shared among the federal, state and local governments. There is no doubt that considering the vast area of uncultivated land coupled with the natural fertility of its soil, Nigeria has great agricultural potentials. The Nigerian rice sector is special within the West Africa context. First, rice is primarily a cash crop in Nigeria (produced primarily for the market). Therefore, in rice producing areas, the enterprise provides employment for more than 80% of the inhabitants in various activities along the production/distribution chain. Some remarkable developments have also taken place in the sector particularly within the last ten years. Both production and consumption have increased during the period, although the increased production was not sufficient to match the consumption leading to imports to make up for the shortfall. Since rice is now a major component of the Nigerian diet and therefore takes a greater percentage of Nigerian agricultural imports, there is considerable political interest in promoting the consumption of local rice. This has made rice a highly political commodity in Nigeria.

It is a statement of fact that increased food and fibre production is a key issue facing developing countries, especially in the African continent. The main reason being that agricultural growth rate in these countries seriously lags behind their ever increasing population. In addition, there are various natural as well as institutional constraints which militate against rapid growth in the agricultural sector. Notably among these are climatic conditions, inadequate and untimely supply of inputs, limited funds and poor technological framework. These issues need to be seriously addressed if the trend must be reversed in the new millennium. Recently, some exciting developments have taken place in the agricultural sector, which should be consolidated. The sector is sustaining the 7% growth rate attained in 2003/2004. This was occasioned by some strategic programmes under the National Agricultural Policy, the National Policy on Integrated Rural Development and the National Economic Empowerment and Development Strategy (NEEDS) which are being vigorously implemented in the various sub sectors within the limits of available resources. This paper will attempt to enumerate some of the experiences and achievements already being recorded under some of these strategic programmes:

### *(a) National Agricultural Policy*

In an attempt to tackle the problems facing the Agricultural Sector in Nigeria, Government has put in place the National Agricultural Policy, which was jointly formulated by national stakeholders and International Development Partners and approved by the Federal Government in 2002. The major components of the National Agricultural Policy feed the National Economic Empowerment and Development Strategy (NEEDS) document. The National Economic Empowerment and Development Strategy (NEEDS) document adequately responds to the demands and strategies of the Millennium Development Goals (MDG).

Specifically, the National Agricultural Policy assigns supportive roles to the government, while investments in the sector are left to the private sector. The broad objectives of the National Agricultural Policy include: Promoting self-sufficiency in food and raw materials for industries; recognizing that agriculture is business, promoting reliance on local resources; diversification of the sources of foreign exchange earnings through increased agricultural exports arising from adoption of appropriate technologies.

### *(b) Agricultural Mechanization Policy*

Realizing that self-sufficiency in food and fibre production is a major index for assessing a nation's developmental effort, policy makers were convinced that modernization of Nigerian agriculture through introduction and development of need-based, home grown agricultural mechanization technologies was a way out of the log-jam of hunger and want. It was on this premise that the National Centre for Agricultural Mechanization (NCAM) was established in 1974. NCAM is under the Federal Ministry of Agriculture and was established as a research and development Centre with the primary mandate to fast- track the positive transformation of the Nigerian agriculture through the use of appropriate mechanization technologies. This mandate is being achieved through the following specific functions: (i) to encourage and engage in adaptive and innovative research towards the development of indigenous machines for farming and processing techniques, (ii) to design and develop simple and low cost equipment which can be manufactured with local materials, skills and facilities, (iii) to standardize and certify, in collaboration with the Standards Organization of Nigeria (SON), agricultural machines, equipment and engineering practices in use in Nigeria, (iv) to bring into focus mechanical technologies and equipment developed by various institutions, agencies or bodies and evaluate their suitability for adoption, (v) to assist in the commercialization of proven machines, equipment, tools and techniques, (vi) to disseminate information on methods and programmes for achieving speedy agricultural mechanization, and (vii) to provide training facilities by organizing courses and seminars specially designed to ensure sufficiently trained manpower for appropriate mechanization.

NCAM, being the only agricultural mechanization outfit with her peculiar mandate is not only accredited by the Federal Government of Nigeria but also standardizes, tests and certifies the production and utilization of agricultural machineries, tools, and equipment in Nigeria. The standardization component is done in liaison with the Standards Organization of Nigeria (SON). For instance, all tractors imported into the country, today must be tested and certified by NCAM.

*(c) Rice Policy*

Rice production in Nigeria is dominated by small holder farmers with 0.5 - 1.5 hectare per farmer, relying on manual labour for all operations. Presently over 52 rice varieties with yield potentials of 2 – 8 tonnes of paddy per hectare and maturity periods of 95 – 140 days have been developed by both National and International Research Institutions. Most of these varieties have been found to be suitable for cultivation in diverse agro ecological zones. Current national demand for rice is estimated at 5.0 million metric tonnes of milled rice while the current production status is estimated at 3.0 million metric tonnes leaving a deficit of 2.0 million metric tonnes which has to be provided through imports. Thus, the urgent need to address the production constraints for increasing output to satisfy domestic consumption and even produce for export becomes paramount. Prior to the oil boom of the 1970s, the government placed a high tariff on imported rice at about 66%. In 1974, the tariff on rice was reduced to 20% and further reduced in 1975. This led to increased importation of cheaper rice which provided disincentive to local farmers who stopped growing rice because they could not compete with cheaper imports. However, during the Nigerian second republic, the elected government decided to restrict the importation of rice and later in December 1980 introduced the presidential task force on rice. Two months earlier, rice was placed under a general import license. Both systems later became embroiled in controversy. From 1985 up to 1995, rice importatation was totally banned. In 1995, a tariff system was re-introduced with a 100% tariff (Wikipedia online encyclopaedia).

*(d) Trade Policy*

Nigeria has employed various trade policy instruments such as tariff, import restrictions, and outright ban on rice import at various times. During the 1970s and early 1980s, increased export earnings coupled with the highly over valued exchange rate of the naira made it possible for Nigeria to finance huge food imports. The high naira exchange rate cheapened food imports and consequently helped to depress domestic prices. Large importation of food items especially rice was allowed into the country at relatively cheap prices. This eroded the competitiveness of domestically produced rice and served as major disincentive to rice farmers.

*(e) Fertilizer Policy*

Nigeria has been largely an importer of fertilizer. Domestic production of fertilizer on a significant scale did not begin until 1987. Subsidy on fertilizer was introduced in 1976. By this, fertilizer which was largely imported by the federal government was distributed to farmers at prices below the cost of importation. Subsidy on fertilizer was completely removed in 1997 before the inauguration of the democratic government in May 1999. After the inauguration, however, the federal government re-introduced fertilizer subsidy to the tune of 25%. After six months in February 2000, government completely liberalized procurement, trade and distribution of agricultural inputs including fertilizer. By this policy, the authority to import agricultural inputs including fertilizer became vested in the hands of private individuals and firms, (Daramola, 2005).

*(f) National Seed Policy and Seed Development Plan*

A policy that stresses the importance of ensuring adequate supply of good quality seeds at affordable prices for both rice and other crops is currently in place. The major objective of this policy is to provide a framework for future development of the seed sub-sector through: (i) establishment and governmental support of varietal improvement, registration, release and multiplication of released varieties, (ii) re-organisation of both the public and private sectors involved in the seed industry and (iii) encouragement of the private sector participation and take-over by the seed industry.

*(g) Land Policy*

In Nigeria, land provides source of livelihood to over 90 percent of the population. This explains why the first law of society was a land law. Prior to the promulgation of the land use decree of 1978, different land law operated among the regions of the federation. In the Northern region, the land belongs to the state. The emirs and chief supervised the use of land and issued out certificates of occupancy. The people have the right to use the land but not to own it. But in the Eastern region there were individually owned small pieces of land. Also, the communal lands were owned by the village, town or clan. The ownership of land in the Western region was a bit similar to that of the East. There were the communal (held on tribal, village, clan or family basis), collective (a group of people buy and share lands) and individual ownership. On the agricultural scene, millions of independent peasant farmers control land and cultivate a variety of crops including rice. The land use decree was promulgated in 1978. The decree did not alter the Northern region traditional land tenure system but changed the system that operated in the East and Western regions. The ownership of land in each state was vested in the state governments in trust for the people of the state.

*(h) International Trade Policies Affecting the Nigerian Domestic Rice Production*

There is virtually none. Nigeria is an importing country and may be affected by international trade policies only to the extent that such policies affect countries from which Nigeria imports rice. Nigeria does not have the 'Agreement on Agriculture' reduction commitments. She does not have either regional or bilateral trade agreement that affects rice trade and production. But as stated earlier, the structural adjustment programme tended to have restored Nigeria's ability to produce rice, having created an environment that made local production somewhat profitable but not fully competitive with imports, (Akande, 2005)

**PROVIDING NIGERIA'S RICE REQUIREMENTS THROUGH SERIF**

The rice needs of Nigeria will be significantly addressed if the following can be considered.

(i) The present agricultural mechanization level in Nigeria shows that agricultural work done with engine powered technology is estimated at only 3%, hand tools application stands at 90% and animal drawn technology takes 7% (Onwualu and Pawa, 2004). The number of serviceable tractors available nationwide is estimated at 30,000 units. Further actions are therefore required from the Federal government, with the support of development partners, such as JICA, JIRCAS, and the World Bank to provide incentives for appropriate mechanization intervention.

(ii) Sustainable agricultural production is realized by balanced application at farmers' field of both (1) Varietal improvement through biotechnology and (2) the improvement of rice ecological environment through eco-technology. In comparison to the biotechnological research and technology development, eco-technological research and technology development have been largely neglected in Nigeria. The eco-technological research and development gap has to be bridged.

(iii) Low rice yield despite huge investment in agricultural inputs is a serious issue to be addressed. Thus, the 'sawah' eco-technology is the prerequisite condition to apply the three green revolution technologies of High Yielding Varieties, Fertilizer and Irrigation successfully.

(iv) There is a wide gap between rice yield on research fields (7-9 ton/ha) and farmers' field (1-2.2 ton/ha) in Nigeria. This is because results of research work in the various national research institutes are not well transferred to the farmers. To address this problem, the 'Sawah' Project can use the Participatory Learning and Action Research (PLAR) as well as Participatory Varietal Selection (PVS) approaches to bridge this gap.

(v) Upland ecologies are cultivated at the expense of the forest leaving the lowland under-utilized. This situation encourages deforestation and consequently contribute to global warming. Lowland development should be the major focus of the 'Sawah' eco-technology project. This will help to combat global warming too.

**Conclusion.**

Many a times the Nigeria government does not have problem with policy making. Policy implementation however has been lacking, largely because the political will to make them succeed has been weak. However, the current Presidential Initiative on rice provides the enabling environment for private sector-led rice production. Rice farmers and processors receive government support through provision of inputs and services at affordable prices as private sector operators. The Presidential Initiative on Rice Production, Processing and Export laid a solid foundation for sustainable rice production and development in Nigeria. However, a lot still needs to be done in order to make rice production and processing to become internationally competitive especially under zero tariff regimes. There are a few areas that need closer investigation and attention by policy-makers in order to make the rice sub-sector more competitive. These areas include; strengthening of the rice processors associations by building their capacities through training on value addition, consumers' preference and packaging.

**References**

Akande Tunji 2005. An overview of the Nigerian rice economy www.unep.ch/etu/etp/events/Agriculture/nigeria.pdf).

CBN/NISER 1992. Annual Economic Report.

Daramola Biyi, 2005. Paper presented at the `Workshop on Rice Policy & Food Security in Sub-Saharan Africa' organized by WARDA, Cotonou, Republic of Benin, November 07- 09, 2005. http://www.adrao.org/workshop/RicePolicy/Biyi/Biyi.D.Nigeria.

Nigeria National Report, 2006. International Conference on Agrarian Reform and Rural Development. Porto Alegre, 7-10 March 2006

Onwualu, A. P. and N. P. Pawa. 2004. Engineering infrastructure for the manufacture of Agricultural engineering machines in Nigeria: The role of NASENI. Proc. 2nd International Conference of the West African Society of Agricultural Engineering, Kumasi, Ghana. 20-24 Sept. 2004.

# The Study on "Development of Improved Infrastructure and Technologies for Rice Production in Africa (DIITRPA)"

Naoya Fujimoto

*Project Leader to DIITRPA, Rural Development Division (RDD), Japan International Research Center for Agricultural Sciences (JIRCAS), Tsukuba, Japan*

**Abstract**

Japan International Research Center for Agricultural Sciences (JIRCAS) began the study on Developing Improved Infrastructure and Technology for Rice Production in Africa (DIITRPA) in 2008 financially aided by the Ministry of Agriculture, Forestry and Fisheries in Japan. DIITRPA was designed to explore ways to increase rice production in accordance with diverse forms of rice ecosystems in Africa, especially to improve farmland and facilities and develop farmers' cultivation skills in rain-fed lowland areas, by improving methods for rice field construction and cultivation management, introducing appropriate cultivars, and providing seeds as well as equipment and materials. At the same time, on-the-job-training for extension workers and irrigation engineers was to be also carried out, and a technical manual for dissemination of the results of this study will be made by consolidating the results. This study shares the same goal with CARD (Coalition for African Rice Development) in increasing rice production in Africa. A basic study of rice production in rain-fed lowlands was conducted in 2008 in the eastern and western regions of sub-Saharan Africa through site visits in each region. Based on that basic study, it was decided to execute a verification study in rain-fed lowland areas in Ghana from 2009 and in Ethiopia from 2010 utilizing the results in Ghana. The verification study is being done with farmers at selected model sites on the following topics: establish construction methods of farmland and simple irrigation facilities suitable for variable topographies and water resources, improved cultivation techniques, organize farmer groups to manage facilities, machinery and materials and draft an instruction manual for leaders of farmers to utilize based on field experience and local conditions. During the validity study in Ghana, JIRCAS encountered several difficult conditions of both topography and precipitation, but a successful result has been achieved during three and a half years' of activities and after receiving valuable collaboration from counterpart institutes in Ghana.

## Introduction

In 2008, the Japan International Research Center for Agricultural Sciences (JIRCAS) started a study on Development of Improved Infrastructure and Technologies for Rice Production in Africa (DIITRPA). JIRCAS was financially aided by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan. The study which has gone through several stages is currently focusing on drafting a technical manual in which many findings that JIRCAS has acquired through the three-and-a–half years validation study in Ghana will be highlighted and documented. JIRCAS has recently been in the stage of adapting experiences gained to other countries in Africa. This paper explains ideas of dissemination based on the activities implemented so far by JIRCAS.

*Why JIRCAS started the study*

Demographic study shows that rapid population growth in Africa is observed, so food shortage in Africa has been one of the world-wide serious problems anticipated in the near future. On the other hand, since food production in Africa is still not sufficient to meet demand, imports of food from Asia and North America are currently observed. Rice consumption in Africa started increasing during the 1970s. This increasing demand for rice, made governments of Western Africa and assisted by FAO, to establish the West Africa Rice Development Agency (WARDA, currently "Africa Rice Center") WARDA has produced new rice varieties in Africa (NERICA) since its establishment, and Japan has supported disseminating NERICA varieties, but NERICA hasn't been popular yet in African countries because of the poor experience of rice cultivation, etc. In May 2008, the Japanese government, together with the Alliance for Green Revolution in Africa (AGRA), developed the concept of the Coalition for African Rice Development (CARD) that targeted to double rice production in ten years, and started various studies to fulfill the goal simultaneously.

*Key points to developing rice cultivation*

Rice needs three key components of natural environment such as (1) appropriate temperature, (2) enough accumulated-sunshine-duration and (3) precipitation to achieve high yield. Agronomic efforts have been done to create good species of rice, effectively grown under particular circumstances of temperature and sunshine-duration at the particular area where rice is planted. On the other hand, irrigation engineers have worked hard to prepare better condition of irrigation and drainage where enough water resources for rice cultivation isn't sufficient. Dams, head-works (weirs) and canals are effective infrastructure to propel rice production for large-scale farmland, such as more than ten thousand ha. Besides constructing such huge facilities, practicing micro irrigation method, equipping pipe-lines, using sprinklers and growing cover crops are also implemented in developed countries. JIRCAS, however, adopted another method of implementing rice paddy field development using grass-roots activities.

## Materials and Methods

A basic study of rice production in rain-fed lowlands was conducted in 2008 in the eastern and western regions of sub-Saharan Africa through site visits in each region. Based on that basic study, it was decided that a verification study be executed in rain-fed lowland areas in Ghana from 2009. The verification study was done with farmers at selected model sites on the following topics: (i) establish construction methods of farmland and simple irrigation facilities suitable for variable topographies and water resources, (ii) select suitable varieties and improved cultivation techniques, (iii) organize farmer groups to manage facilities, machinery and materials. At the same time, on-the-job-training was provided to extension workers as well as farmers. A technical manual was finally drafted for disseminating the result of the study based on local conditions.

## Results and Discussion

*(1) Lessons learned in Ghana*

In West Africa, particularly Ghana and Nigeria, a special way of rice cultivation called "Sawah" system was being transferred to farmers. This activity was led by Prof. Dr. Wakatsuki, of Kinki University in Japan and recorded results have been very remarkable. Using these experiences, JIRCAS decided to facilitate the transfer and practice of "Sawah" system. According to Buri et al. (2009), technical definition of "Sawah", or "Suiden" (in Japanese), is a bunded and well-leveled rice field with an inlet for irrigation and an outlet for drainage. JIRCAS tried to trace the same method of (a) bunding paddy field, (b) leveling and puddling using power tiller (PT) and (c) delivering irrigation water to the farming plots. "Sawah" system has no tendency of decreasing yield even if fields are continuously cropped for many years. For example, Japanese experience shows that, cultivating rice on the same piece of land for over 2000 years has posed no serious problem as a result of its continued use.

*(2) Technical aspects to do validation study*

Validation study sites of JIRCAS were chosen to collect data. However, the data was not collected during the activities of developing-farmers'fields but was rather collected with JIRCAS's input, by field extension staff. Such data was to be included the technical manual. So, under site selection, the following creteria was considered: (i) accessibility to the project site, (ii) whether famers have experience of rice production or not, (iii) whether water resources are enough or not, (iv) whether soil condition is wet or dry, (v) whether dry season crops are planted or not, (vi) whether palm trees are existing at the selected site or not (vii) whether farmers organization exist or not and (viii) whether the land user is as same as land owner or not.

| Criteria | Points | Example | Why it is important? |
|---|---|---|---|
| (1) Access | 1-5 | 4 | For dissemination |
| (2) Experience of rice production | 1-2 | 2 | Yes = 2; No = 1 |
| (3) Water resources | 1-2 | 1 | |
| (4) Soil condition | 1-2 | 2 | Dry = 1; Wet = 2 |
| (5) Dry season crop | 1-2 | 2 | |
| (6) Palm tree | 1-2 | 2 | For leveling |
| (7) Farmers Organization | 1-2 | 2 | |
| (8) Land user | 1-3 | 2 | |
| Total | 8-20 | 17 | |

Source: A discussing material by Dr. Fukuo (2009.11.04)

*(3) Canal design*

During the validation study in Ghana, JIRCAS encountered several challenges regarding conditions of both topography and precipitation. JIRCAS recommended and financially supported the constructions of canals to convey irrigation water to the fields. These canals varied depending on the nature and type of valley. Some of the designs used to better water management in Kumasi, is shown in Figure 2. Some of these types include (i) dyke/weir type, (ii) dual canal type and (iii) a combination. All of these techniques are effective on paddy fields of bunded and levelled conditions which are similar to traditionally-practiced paddy fields in Japan.

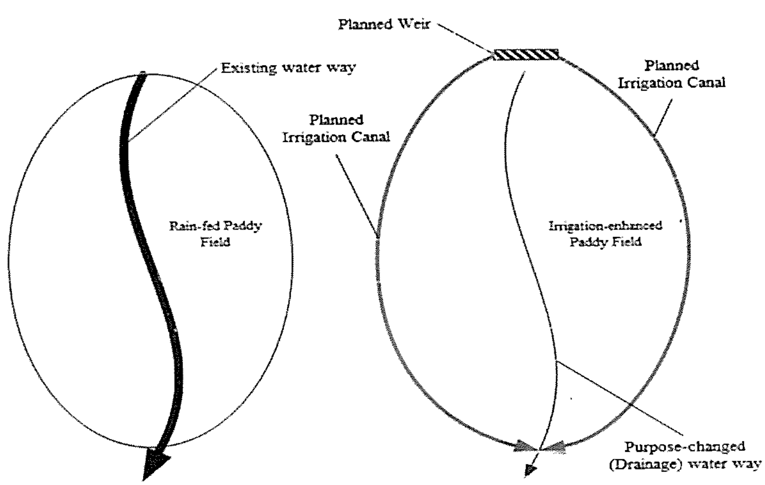



**Fig-2:** A typical betterment, left to right, for rain-fed paddy field.

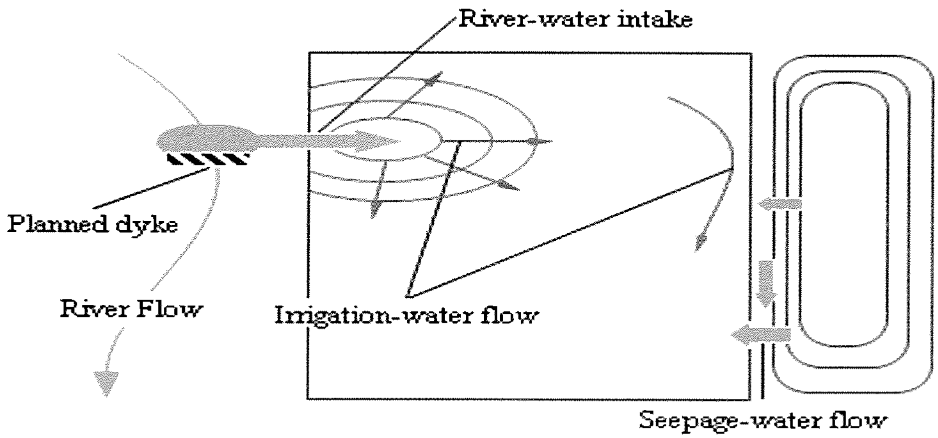



**Fig- 3**: A proposed betterment for upper portion of Nsutem-B site.

*(4) On the job training*

In 2008, JIRCAS was supported by the Soil Research Institute (SRI) and Crops Research Institute (CRI) both of the Council for Scientitifc and Industrial Research (CSIR) to choose project sites since they knew the places and had kept good relation with farmers. Recognizing and understanding the role of extension officers (EOs) JIRCAS asked the Ministry of Food and Agriculture (MOFA) in Ghana and through its District offices, they assisted in information dissemination. In FY 2009, experts from SRI and CRI, who have knowledge of the land conditions of the project sites conducted on-the-job trainings (OJTs) for EOs, who are staff of MOFA. In 2010, JIRCAS expanded the coverage to 8 sites including 20 farming plots and conducted the same activities on rice production as was done the previous year by the experts. Extesion officials, who were trained the previous year, were made to conduct OJT for farmers in several farming communities covering the operational areas of those Extension Officers. The excerise was basically successful, even though several challenges were encountered.

*Social Aspects to do validation study*

*(i) Extention Officers (EOs)*

Rice farmers are faced with a lot of challenges under the traditional system since rice responds very much to climate differences that are not predictable. Much experience can guide farmers to prepare and overcome critical situations by finding solutions to challenges. Perfect timing of fertilizer application and/or pesticide is not easy for farmers to easily understand. Information about pests and deceases could be conveyed by experienced officials to farmers. So the role of EOs is of high importance. Effective extension delivery is one of the fastest ways of achieving the goal of increasing rice yields.

*(ii). Farmers organization*

Rice production in its history needs collaborative work particularly during transplanting and harvesting since it will avoid birds attack and promote the production of better quality rice. According to Piper (1993), "As ways of controlling water were developed, societies changed further, investing ever more in the land for terracing, transplanting rice, and eradicating pests, and the great kingdoms of South-East Asia have usually been based on irrigated rice production." In fact, rice farmers have sometimes formed self-defense forces to confront bulling clans who took all products when harvested, and some of the forces became worriers and worrier's groups and governed districts or even states in old historical Japan. However, in Africa, practical farmer's group formation shouldn't be over expected, but individual farmers should be helped to carry out their agricultural practice, such as transplanting or using power tillers.

*(iii). Land tenancy agreements*

Rice cultivation needs a lot of farming space and time. It takes several years to completely and effectively develop land. In addition, the use of the power tiller and its effectiveness requires several years before farmers can earn enough money to be able to pay for its cost and maintenance. Hence, land tenancy agreements should be designed to cover a minimum of five years period or ideally ten years.

*(iv). Power tiller renting agreement*

The power tiller is relatively expensive for individual farmers to purchase. So it is usually better to be owned by group or organization. It is not easy for farmers who are not well resourced to operate and maintain the power tiller to be used over a longer period of time. JIRCAS employed a measure of power tiller agreement by renting one to a farmer group. JIRCAS suggested to extension officiers to let the group form power tiller maintenance committee with nominated president/chairman who represent the group and be responsible for the proper management/usage of the power tiller during the duration of rented period. The tenancy, however, differed from place to place.

### *(2). Lessons learned in Ethiopia*

*(i). Conditions*

In Ethiopia, there wasn't any experience in using power tiller in the lives of farmers involved in the JIRCAS project. Although rice cultivation was introduced into Ethiopia some several decades ago, land preparation is still being done by the use of oxen. Even though controlling oxen is very difficult, and the plow made of iron is a kind of house treasure for them, several factors should be carefully considered when introducing modern machinery into such a society.

*(ii). Post-harvesting technique*

Post-harvesting technique in Ethiopia is far behind and lucks modern techniques. The Farmers use oxen to thresh rice as it is done for tuff (Ergrostis tuff), which is one of the staple serials in Ethiopia. It is said that the stepping on tuff is effective because it is difficult to dehusked. While rice has a different nature, farmers tend to use same techniques of threshing beause this technique is popular amongst them.

*(iii). Lack of Extension Officers (EOs).*

The agricultural extension system in Ethiopia is not well organized as offcers are not well trained particularly in the field of rice cultivation. The most serious problem is that extension officers are frequently changed, i.e. posted to new places or districts at the end of each year. It was therefore very difficult for JIRCAS staff to equip EOs with good quality rice production techniques since they change frequently.

### *(3). Future prospect of disseminating of "Sawah" system, or Asian-type paddy field, in Africa.*

JIRCAS would like to apply the techniques mentioned above at several sites in Ethiopia, and finalize a technical manual. Since the first visit to Ethiopia by JIRCAS staff in 2009, several validation study sites in the Amhara Region of Ethiopia have been selected where water resources are enough to implement the study. In Ethiopia, "Sawah" system is not popular, so JIRCAS used the term Asian-type paddy field instead, which can easily be recognized by local staff and farmers.

### *(4). Draft Manual*

Currently, a draft manual is being prepared. JIRCAS recognizes the importance of compiling the manual in local languages when it is finally delivered to EOs as well as farmer's group. As such the draft manual would be revised after government officers, EOs and researchers have read through it and made any suggestions or comments. JIRCAS compiled the first draft in 2009, and delivered to EOs and farmers inside JIRCAS experimental plot and received several comments from them. On 28th October 2011, MOFA held a technical committee to check the contents of the technical manual and carry out further inspection of its contents as well as its scope.

(5). ***Recommendations for disseminating "Sawah" system to other countries (in the future)***

*(i). Rainfall (Precipitation)*
Adequate water is necessary to start the "Sawah" system. According to Fujimoto (2005), 800mm - 1,300mm of annual precipitation is the threshold of choosing policy of cultivating rice or wheat in People's Republic of China. So rainfall is one of the basic indicators to decide whether rice is the appropriate crop for a particular area or not. Under high-grade management of rice, such as cropping two or three times a year, or highly mechanized rice cultivation, precipitation should be carefully checked so as to plan what kind of rice production system one would like to apply in the field.

*(ii). Temperature*
Temperature is not a killer-factor that influences rice cultivation within a particular area. Japanese experience of long history of rice cultivation shows that the production area for rice cultivation aimed north and has finally reached the most northern island of Hokkaido where average monthly temperature ranges from 4.6°C (January) to 21.7°C (August). These lessons/experience show how temperature can be overcomed with human technology for rice cultivation. Mountainous area like Ethiopia should carefully consider the lowest temperatures during the rice cultivation season, and special consideration/treatments should be applied, such as introducing low-temperature tolerant species, or counter-measure management, such as keeping deep water in the paddy field during the nights.

*(iii). Land shape (slope)*
Concerning the slope of the land, little slope-area is recommended for Sawah system, since gravity irrigation is easier to be applied than in flood-plain areas where irrigation water runs from highest part of the command area to the lowest part. Flood-plain areas are usually installed with big-project facilities to convey much water both for irrigation and drainage, but the cost of such projects is too large for individual farmers to own. "Sawah" system are not meant to be applied to vasts land where professional designing is required before any good results can be obtained.

*(iv). Accessibility*

Project sites should be located at freely accessible areas, so that farmers who are close-by can observe and see for themselves, developed sawah fields. It is for this reason that JIRCAS considered accessibility as one of the criteria for selecting validation study sites. Good access road is important for transporting produce as well as for moving machinery (power tillers, tools, etc) to project sites.

*(v). Conditions of EOs*

In Africa, if the government of a country has not got a strong and well organized extension system to help farmers improve their agricultural practices, nor extension officiers to be dispatched to rural areas, this need to be pointed out to such government and its importance emphasized, before you actually enter into project sites. You cannot do any advanced technical activities in the rural area without good EO who understand local languages.

*(vi). Stage of mechanization in the area*

Mechanization is not easy to be achieved within several years, since the power tiller needs continuous operation and maintenance (O&M) when introduced to a particular site. Spare parts are needed and sometimes a blacksmith is needed to fix the machines. According to experience from South-East Asia, dissemination of motor-bikes is one of the key indicators for introducing power tiller for the first time. When machinery become popular, a lot of tools to fix machines and factories to provide spare parts would be required in order to maintain machines in good condition.

*(vii). South-south collaboration*

Importance of field-visit by farmers is often cited by many experts of various research fields. A maxim of 'Seeing is believing' is well observed in the dissemination of "Sawah" system too. JIRCAS invited three Ethiopian experts to Ghana in February 2011 to participate in the Steering Committee meeting and a field visit to the project sites in Kumasi was successful. All participants were satisfied with seeing the "Sawah" fieds with their own eyes and had discussion with farmers and EOs at the project sites.

**Acknowledgements:**

I would like to express my gratitude to the Ministry of Food and Agriculture (MOFA), CSIR-SRI and CSIR-CRI in Ghana who are the counterpart Institutes under the Joint Research Agreement (JRA) to help JIRCAS staff conduct prevalidity and validation studies. The study was financially supported by MAFF in Japan.

**References**

M. M. Buri, R.N. Issaka and T. Wakatsuki (2009): The "Sawah" system of rice production, CSIR-SRI, Ghana

N. Fujimoto (2005): Diversity of agricultural water management -An analysis of the policies in the People's Republic of China-, Research Report #44, pp.23-65, National Institute of Rural Engineering in Japan

J. M. Piper (1993): Rice in south-east Asia -cultures and landscapes-. Oxford University Press, Kuala Lumpur, Malaysia, 16-17.

# Agro-forestry and 'Sawah': A Sustainable Land Use System for Socio-economic and Environmental Benefits in Ghana.

Ebenezer Owusu-Sekyere
*Forestry Research Institute of Ghana, UP Box 63, KNUST, Kumasi. Ghana.*

*Abstract*

Farmers in Ghana practice shifting cultivation where when the land becomes unfertile, the farm is abandoned in search of more fertile land for cropping. Cocoa farms are established on uplands whilst the lowlands are used for 'sawah' development. The synergy of silicon in cocoa and rice may suggest that integrating cocoa agro-forestry into the 'sawah' system has very high potential socio-economic and environmental benefits. This paper comes out from two publications. The farm activity schedules for cocoa and rice cultivations do not coincide but overlap within the farming season. Farmers who may be producing both farm commodities will be occupied throughout the year and will be rewarded with commensurate incomes and food all the year round. The major hindrance to this agricultural system is land ownership and use rights. There is the need for secure individualized title, correlated registration of titles and introduction of new attitudes toward land. Tenancy can provide the means by which landowners and the landless may join their respective resources in a productive and complementary manner. However, structural framework in which farmers (tenants and landowners) can work together will be the panacea for sustainable socio-economic and environmental benefits.

## Introduction

In Ghana, farmers continuously cultivate the land for a maximum of five years and abandon this piece of land due to loss of soil fertility. Subsequently, new fertile land (i.e. forestland) is sought for farming in the same way. Cocoa farms, however, can occupy the same land management unit for more than 50 years (Owusu-Sekyere *et al* 2004). 'Sawah' rice on the other hand is capital and labour intensive especially during the preparation of the 'sawah' field for rice based cropping system for the first time or season. After development the 'sawah' field can be cultivated for as long as may be required. The major activities after this are repair and maintenance of the 'sawah' field in the subsequent cropping seasons and can be done for years. Cocoa farms are established on uplands whilst the lowlands are used for 'sawah' development. Hence, the uplands and the lowlands constitute the 'sawah' ecosystem. The major hindrance to this agricultural system is land ownership and use rights.

It is very uncommon for a farmer to crop both uplands and lowlands due to different ownership, use rights and different crop preferences. However, if a single farmer could crop both the upland and the lowland to cocoa and 'sawah' rice, respectively, biodiversity would be restored, effective and efficient land use management system will be developed, income will be intensified and diversified and land conflicts will be avoided. But if different farmers should crop the upland and lowland to cocoa and 'sawah' rice, respectively, the above economic and environmental benefits may be difficult to achieve. Therefore, all efforts should be made to ensure socio-economic and environmental harmonies between land users.

**Methodology**

This paper was developed from "Extending Cocoa Agro-forestry into 'Sawah' Ecosystem in Ghanaian Inland Valleys" published by Owusu-Sekyere et al., (2010) and "Land Tenure Negotiations for Sustainable 'Sawah' Cropping Systems in Ahafo-Ano South District of Ashanti Region, Ghana" submitted for publication by Owusu-Sekyere et al., (2011). These studies were carried out in three 'sawah' rice and cocoa growing communities (Adugyama, Amakom and Biemso No. 1) in the Ahafo-Ano South District in Ghana.

**Results and Discussion**

Generally, in Ghana, land preparation for farming begins in the dry season (November to March) and sowing or planting begins in early March to July in the rainy season every year. Maintenance of the farms does not follow any specific time frame but weeding is done two or three times in a year. Cocoa farming is considered one of the most lucrative farming activities in Ghana. Cocoa plantations are established together with food crops. Cocoa trees start bearing fruits after 3-5 years. Though the new cocoa hybrids fruit all the year round, the peak period of harvesting is done from November to March corresponding to the dry season of the general cropping season each year (Owusu-Sekyere et al., 2010).

From the farmers` activity calendar (Table 1), land preparation, planting and harvesting food crops and the cocoa plantation are concurrent. Lowland rice is grown between the months of July to September every year. The overlap of land preparation for rice and other cropping systems (food crops and cocoa) extends for one month (April). Rice planting is delayed for about two months and harvesting is done three months after planting for a month. Thus, during the peak months for the other food crops and cocoa seedlings planting and harvesting, rice cultivation and harvesting is delayed for two months (Table 1). Weeding, pest and diseases control and other activities are done as and when they become necessary and do not have particular time frames

**Table 1:** Farmers` monthly activity calendar for the year for the establishments of farms

| Farm type | Farmers yearly activity calendar (month) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Mixed food crops | Land preparation | Land preparation | Land preparation | Sowing/planting | Sowing/planting | Harvesting/processing/marketing, etc | Harvesting/processing/marketing, etc | Harvesting/processing/marketing, etc | Harvesting/processing/marketing, etc | Harvesting/processing/marketing, etc | Harvesting/processing/marketing, etc | Harvesting/processing/marketing, etc |
| Cocoa plantation | Land preparation | Land preparation | Land preparation | Sowing/planting | Sowing/planting | Sowing/planting | Sowing/planting | No activity (leisure) | No activity (leisure) | No activity (leisure) | Harvesting/processing/marketing, etc | Harvesting/processing/marketing, etc |
| Rice ("Sawah") | Land preparation | Land preparation | Land preparation | Land preparation | No activity (leisure) | No activity (leisure) | Sowing/planting | Sowing/planting | Sowing/planting | Harvesting/processing/marketing, etc | Harvesting/processing/marketing, etc | Harvesting/processing/marketing, etc |

Land preparation — Sowing/planting — Harvesting/processing/marketing, etc — No activity (leisure)

Rice is cultivated in inland valleys and on uplands. The yield of upland rice is low (less than 1.6 t $ha^{-1}$) as compared to about 2.5 t $ha^{-1}$ for lowland traditional rice and more than 4.5 t $ha^{-1}$ under the 'sawah' rice technology in Ghana (Issaka *et al* 2007). The term 'sawah' refers to a levelled, bunded and puddled rice field with water inlet and outlet to control irrigation and manage soil fertility. The 'sawah' rice farming system is now catching up with farmers throughout Ghana. The 'sawah' field is invariably in the lowlands i.e. valley bottoms or flooded areas. But the uplands play major roles in maintaining the rice fields for sustainable production. Hence, the uplands form part of the 'sawah' ecosystem. The wetlands or inland valleys belong exclusively to the paramount chief who has the oversight responsibility over farmlands of towns and villages under his traditional authority whilst the uplands belong to tribes, clans, families and individuals (both indigenes and migrants). There have been great uncertainties about securing the best tenure options for suitable valley bottoms for rice cultivation that can guarantee farmers continuous and sustained rice production.

Cocoa grown in the uplands has been shown to release silicon during leaf decay and has the potential to be transported down the slope to fertilize the lowland where rice is cultivated (Owusu-Sekyere et al., 2010). Silicon is an important nutrient for the optimal growth and sustainable production of rice (Epstein 1999, Epstein & Bloom 2005, and Ma *et al* 2006) (Fig.1). This synergy of silicon in cocoa and rice may suggest that integrating cocoa agro-forestry into the 'sawah' system has very high potential benefits. It ensures effective and efficient resource utilization above and below ground leading to environmental stability both in the upland and the lowland. It also provides an opportunity for some form of activity linked with income generation all the year round without sacrificing degradation of the two farms, no period of unemployment and few leisure times on the calendar (Table 1 and Fig.1) of the farmer as earlier reported by Owusu-Sekyere et al., (2010).

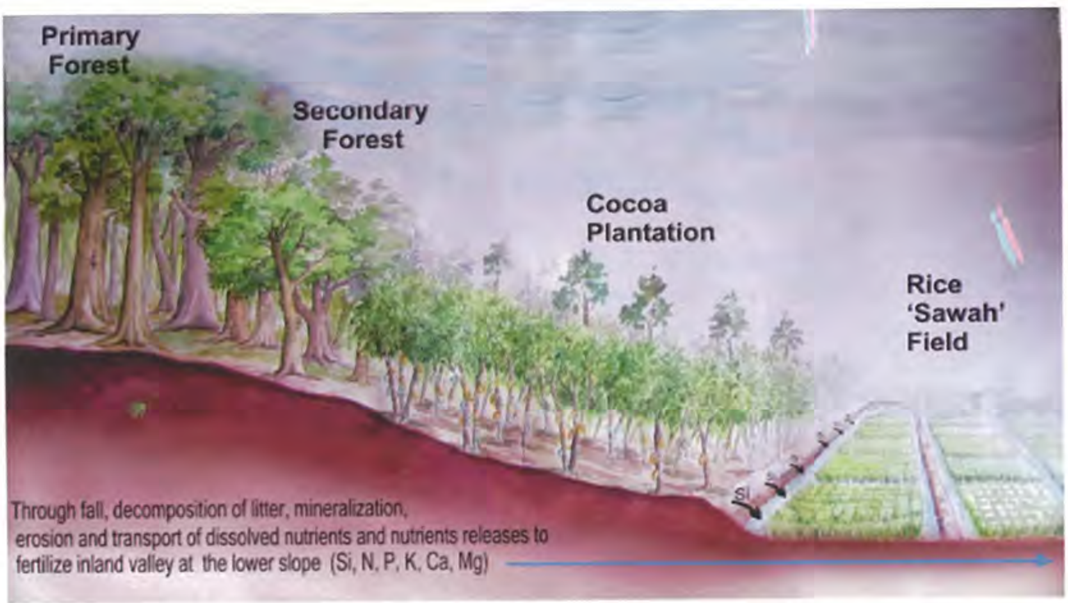



**Figure 1.** Extending cocoa agro-forestry into 'sawah' ecosystem in Ghana

Farmlands are obtained through inheritance given by family head and as gifts. Tenants accessed land by renting for a year, fixed tenancy for two (2) years and tenancies beyond 2 years are very few. However, few individuals own farmlands. From survey of land ownership of wetlands of 'Sawah' farmers, as much as 63% hire or rent land, 11% were for free, individual ownership was about 12% and about 14% cultivated on family lands. Land tenure problems can be solved by integrating formal law and social agreements to enhance economic efficiency.

## Conclusion

It is concluded that farmlands (both uplands and lowlands) could be cultivated with cash (cocoa) and food (rice) crops. But the Tenure insecurity tends to be less important for short-term inputs than for capital long term investment. Any attempt to promote 'sawah' should ensure creation of secure individualized title, correlated registration of titles and introduction of new attitudes toward land. Tenancy can provide the means by which landowners and the landless may join their respective resources in a productive and complementary manner. However, structural framework in which farmers (tenants and landowners) can work together to improve their financial, social positions and to maintain environmental quality should be the ultimate.

## References

Epstein, E (1999) Silicon. Ann. Rev. Plant Physiol. *Plant Mol. Biol.* 150, 641-664.

Epstein, E. & Bloom, A. J. (2005) In *Mineral Nutrition of Plants*: Principles and Perspectives. 227-231 (Sinauer Associates, Sunderland, Massachusetts).

Issaka R.N., Buri M.M., Wakatsuki T and Dwomo O.(2007). Review of rice policies on rice production in Ghana. Paper presented at the 4th International Conference of the African Soil Science Society organized at the Ghana Institute of Management and Public Administration (GIMPA), Accra, Ghana. 7th - 13th January 2007.

Ma, J. F., Tamai, K., Yamaji, N., Mitani, N., Konishi, S., Katsuhara, M., Murata, M. & Yano, M. (2006) A silicon transporter in rice. *Nature* 440, 688 - 691.

Owusu-Sekyere, E., Cobbina, J. & Wakatsuki, T. (2004) Decomposition, Nutrient Release Patterns and Nutrient fluxes from Leaf Litters of Secondary Forest in Ghana. *Ghana Journal of Science. Vol. 44.* Pp 59-72.

Owusu-Sekyere, E., E., K. Nakashima & Wakatsuki, T. (2010) Extending Cocoa Agro-forestry into 'Sawah' Ecosystem in Ghanaian Inland Valleys. *Ghana Jnl. Agric. Sci.* 43, 37-44.

Owusu-Sekyere, E., S. B. Samar & Wakatsuki, T. (2011) Land Tenure Negotiations for Sustainable 'Sawah' Cropping Systems in Ahafo-Ano South District of Ashanti Region, Ghana. *Submitted to Ghana journal of Forestry 2011.*

# Socio-Economic, Dynamics of Farmers Associations and Adoption of 'Sawah' Rice Production Technology in Nigeria and Ghana.

Oladele O.I[1]. and Wakatsuki T[2].

[1]*Department of Agricultural Economics and Extension, North West University (Mafikeng Campus), Private Bag ×2046, Mmabatho 2735, South Africa;* [2]*Faculty of Agriculture, Kinki University, Nara 631-8505, Japan)* oladele20002001@yahoo.com

**Abstract**

The adoption of new agricultural techniques of which 'sawah' rice production is an example, is a key route out of poverty for many in the developing world. This paper analyzed whether and how a farmer's decision to adopt a new technology depends upon the adoption decision of other farmers in their social group, which, unlike most of the existing literature, the paper is able to identify precisely. The use of various technologies depends on socioeconomic variables and the existence of different dimensions of social dynamics. Social dynamics is especially important in determining whether households have access to, and therefore use, different technologies. Although different studies have looked at social dynamics in terms of membership in groups, there is the need to differentiate different kinds of social dynamics as they influence technology adoption differently. Social dynamics measured as bonding, bridging, and linking influence technology adoption. Overall the evidence suggests that network effects are important for individual decisions, and that, in the particular context of agricultural innovations, farmers share information and learn from each other. Individual adoption decisions depend upon the choices of others in the same social networks. Since farmers anticipate that they will share information with others, farmers are expected to be more likely to adopt when they know many other adopters. Dynamic considerations, however, suggest that farmers who know many adopters might strategically delay adoption to free-ride on the information gathered by others. The specific application of the socio-economic and dynamics of farmers association to adoption was explained through a cross sectional data collected from adopters and non adopter of 'sawah' rice technology in Ghana and Nigeria. The paper concludes that the externalities which play important role in technology-adoption decisions are network, market power and learning externalities. The study recommends investments, especially by development organizations, in strengthening these different forms of social dynamics by supporting local kinship or community groups that generate social dynamics, promote farmer access and links with external organizations that can act as sources of information and technologies for farmers, as well as links with other farmer associations and groupings from whom they can learn.

**Keywords**: socio-economic, dynamics, social groups, networks, externalities adoption, 'sawah', rice.

## Introduction

The importance of farmers' adoption of new agricultural technologies has long been of interest to agricultural extensionists and economists. Several parameters have been identified as influencing the adoption behavior of farmers from qualitative and quantitative models for the exploration of the subject. Social scientists investigating farmers' adoption behavior have accumulated considerable evidence showing that demographic variables, technology characteristics, information sources, knowledge, awareness, attitude, and group influence affect adoption behavior. Adoption of innovations refers to the decision to apply an innovation and to continue to use it. A wide range of economic, social, physical, and technical aspect of farming influences adoption of agricultural production technology. Earlier evidences[2] led to the categorization of adoption behavior into innovators, early adopters, early majority, late majority and laggards. This is based on validated studies that the adoption behavior of any agricultural technology would follow a normal distribution curve in a given social system. The increasing importance of rice towards world food security has been stressed through the green revolution in Asia and the increasing consumption of rice among the world's poor. Aker et al (2010) stated that although rice is grown efficiently by small scale farmers, a successful rice economy needs sophisticated engagements from government to develop the economies of scale and scope that permit a low-cost rice system- and engagement that has largely been missing in West Africa.

## 'Sawah' rice production technology

The concept and the term 'sawah' refers to man-made improved rice fields with demarcated, bunded, puddled and levelled rice fields with water inlet and water outlet, which, if possible, can be connected to various irrigation facilities, such as canals, ponds, weirs and springs. Gajigo and Dennning (2010) noted that the presence of irrigation technology is a significant factor in explaining the variation in rice production in West Africa. The 'Sawah' system was introduced through on-farm adaptive research in the two research sites of Gara and Gadza inland valleys, located in Bida, Nigeria in 1988 (Hirose & Wakatsuki, 2002). 'Sawah' based rice production development started with three individual farmers in three villages with 0.1ha in total area in 2001. The establishment of a demonstration field (1.0 ha) at Ejeti village in 2002 galvanized the project. In 2002 the number of farmers increased in the 'Sawah' Package program and by 2003 the farmers increased to fourteen and to eighteen in 2004 from four villages. In 2005, the farmers of the 'Sawah' Package' had increased to 83 from five villages covering more than 20ha area (Fashola et al, 2006). This spread and adoption of 'sawah' which grow in leaps and bounds spreading over additional five states between 2005 and 2010 with over an estimated

10,000 adopters affirms its wide acceptance due to its improvement over the traditional system of rice farming in terms of yield, sustainable land use and the on farm demonstration method whose result in terms of field fact as witnessed by the farmers has been very convincing. Gajigo and Dennning (2010) reported that after controlling rice area harvested and per capital income, both total rice production and yield are significantly correlated with the proportion of the area irrigated.

**Social dynamics and adoption**

The adoption of new agricultural techniques is a key route out of poverty for many in the developing world. Yet, agricultural innovations have often been adopted slowly and some aspects of the adoption process are still poorly understood. Recent studies have shown that, both in developing and developed countries, social networks and peer effects are an important determinant of individual behaviour in a variety of settings. An integral part of sustained poverty reduction efforts is the use of improved high yielding variety seeds and sustainable use of natural resources (Kabubo Mariara et al, 2007). At the farmer level, although there are many factors that influence adoption and use of these technologies, studies have shown that rural communities that are characterized by strong social dynamics have faster rates of technology diffusion and improved environmental management (Claridge T. 2007). According to Woolcock and Sweetser (2007), social dynamics influence the use of technologies differently. For example, technologies that are knowledge intensive may require different forms of social dynamics than those that are labour or input intensive. Studies on the links between social dynamics and agricultural technologies have, however, not differentiated the different forms of social dynamics and how these influence the adoption and utilization of different technologies. Social dynamics or capital is the establishment of norms that permit people to work in groups. Hence social capital is the consequence of intensely rooted cultural habits (Fukuyama F., 2004), and as a result, it is defined differently in different cultural settings. The vast literature on social capital further refines its definition to distinguish between bonding, bridging, and linking social capital.

Social learning and information spillages have been described as important driving forces in models of endogenous growth. Conley and Udry (2000) reported that farmers within a group learn from each other how to grow new crop varieties. In relation to this, externalities have been identified to be important in technology-adoption decisions. The dynamic choices with externalities include the sources such as (i) Network Externalities. -Adopters care about how many other individuals adopt because there is some public-good element to the technology, (ii) Market Power Externalities. -Adopters with market power will care about adoption by others if adopting early implies some advantage in market power; and (iii) Learning Externalities.-Farmers may care about others' adoption decisions if early adopters teach late adopters something.

Bonding social capital is generally defined as closed networks of close friends and relatives or horizontal relationships among equals within a localized community (Claridge T., 2007). It is the social cohesion that takes place between individuals of similar ethnic backgrounds or social status and it is reinforced by working together. Szreter and Woolcock (2004) defined bonding social capital as the trusting and cooperative relations between members who are similar in a socio-demographic sense. Some examples of this type of social capital include formal and informal clubs, groups, or associations established by farming communities in many villages across SSA. These groups may be formed through religious affiliations, local traditional structures, or other localized structures. Bonding social capital is thus characterized by trust and norms that exist within the social structure. Bridging social capital, on the other hand, is widely agreed to be vertical relationships or networks that cross social groupings. These are established between people or organizations that are removed from each other and are in different communities (Claridge T., 2007).

Bridging social capital links networks requiring collaboration and coordination with other external groups to achieve set goals. For example, it can be the link between two local groups from different villages. Leonard and Onyx (2003) use five indicators of social capital (networks, reciprocity, trust, shared norms, and social agency) to define bonding and bridging social capital. Bonding social capital was described as being characterized by dense, multiplex networks, long-term reciprocity, thick trust, shared norms, and less instrumentality, whereas bridging social capital is characterized by large, loose networks, relatively strict reciprocity, and a thinner or different type of trust and more instrumentality. Linking social capital is the engagement of local groups or networks with institutions or agencies in higher influential positions[9]. Through linking social capital, groups of poor people are able to access support, resources, and information from organizations and networks. Woolcock and Narayan (2000) see bonding social capital as operating as a defence mechanism against poverty, whereas bridging social capital is what is required for real economic growth to take place. The three types of social capital, therefore, complement each other, in that the strong bonds existing in bonding social capital are diversified by the existence of bridging social capital, whose bonds are weaker but more cross cutting, hence enabling increased diversity in an otherwise closed community. Linking social capital allows for the accumulation of resources, information, and wealth, which is needed by networks to achieve set objectives. Hence, all three types of social capital can coexist in a community to different extents, but more frequently one maybe more prominent.

The objective of this paper is to examine the influence of social dynamics on the adoption of 'sawah' rice production technology in Nigeria and Ghana.

**Methodology**

The study was carried out in Nigeria and Ghana. It covered 12 fields in Nigeria with 80 farmers, while in Ghana 11 fields in 5 villages with 70 farmers were covered. The field locations in Ghana are in the Ahafo Ano South district. The climate is tropical with two distinct rainy seasons in the south (May-June) and (August-September). In the north, the rainy season is just one (June-September). The choice was necessitated by the fact that all 'sawah' development projects have concentrated on the Ahafo Ano South districts. In Nigeria, most of the fields covered are in Bida area of Niger state, while a village (Pampaida) was covered in Kaduna state and Akure in Ondo state. Villages covered in Bida area include Shabamaliki, Ejeti, Ekapagi, Nasarafu, Etsuzegi and Gadza. Villages covered in Ghana were Adugyama, Biemso No. 1, Biemso No. 2, Fediyeya and Attakrom. Data was collected in June 2010 from all the villages where 'sawah' rice production technology had been introduced and adopters of 'sawah' technology were interviewed. A structured questionnaire with a reliability coefficient of 0.85 was used to elicit information on socio-economic characteristics and social dynamics. Descriptive statistics was used to describe the data while Probit model was used to analyze the adoption with particular reference to the effects on the spread of the technology.

A probit model is appropriate when the dependent variable to be evaluated is dichotomous (Ameniya, T. 1981 and Anim F. D. K and Mandleni, B. 2010). The relationship between the probability of a variable Pi and its determinants q is given as:

$$Pi = \beta qi + \mu i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where Pi=1 for Xi>Z; i=1, 2 ......, n; qi is a vector of explanatory variables and $\beta$ is the vector of parameters.

In the probit model the discrete dependent variable Y is a rough categorization of a continuous, but unobserved variable $Y^*$. If $Y^*$ could be directly observed then standard regression methods would be used (such as assuming that $Y^*$ is a linear function of some independent variables, for example:

$$Y^{*} = \beta_1 X_{1i} + \ldots\ldots\ldots \beta_j X_{ji} + ui \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

In this study, $Y^{*}$ is the adoption of 'sawah' technology which is used as a proxy for $Y^{*}$. The actual model specification is: adoption of 'sawah' technology = $\beta_0 + \beta_1$age + $\beta_2$ educational level + $\beta_3$ membership of farmers' groups + $\beta_4$ Membership of formal and informal clubs + $\beta_5$ Membership of traditional structures + $\beta_6$ Membership of localised structures + $\beta_7$ Shared norms among farmer groups + $\beta_8$ Extent of trust among farmers + $\beta_9$ Transport for easy network + $\beta_{10}$ Network with financial institutions for credit + $\beta_{11}$farming experience + $\beta_{12}$ Land tenure system + $\beta_{13}$ Household size + $u$

The dependent variable Pi is a dichotomous variable which is 1 when a farmer adopts 'sawah' technology and 0 if otherwise. The explanatory variables are: $X_1$ = age in years, $X_2$ =dummy variable for educational level ( formal education = 1, No formal education = 0); $X_3$ = dummy variable for membership of farmers groups (Yes = 1, No = 0); $X_4$= dummy variable for membership of formal and informal clubs (Yes = 1, No = 0); $X_5$ = dummy variable for membership of traditional structures (Yes = 1, No = 0); $X_6$ = dummy variable for dummy variable for membership of formal localized structures (Yes = 1, No = 0); $X_7$= dummy variable for shared norms among farmers groups (Yes = 1, No = 0); $X_8$ = dummy variable for extent of trust among farmers (Yes = 1, No = 0); $X_9$ = dummy variable for transport for easy network (Yes = 1, No = 0); $X_{10}$ = dummy variable for network with financial institutions (Yes = 1, No = 0); $X_{11}$ = farming experience in years; $X_{12}$ = dummy variable for land tenure system (inherited = 1, otherwise = 0); $X_{13}$ = household size in terms of number of persons.

**Results and Discussion**

Table 1 shows the socio-economic characteristics of farmers adopting 'sawah' technology in Nigeria and Ghana. The Table shows that in Nigeria, majority of the farmers are about 43 years of age having quranic form of education, belonging to at least one farmers group and have been farming for about 13 years. The land tenure system is predominantly through inheritance while the mean score for household size among farmers was 4.6. In Ghana, the mean age is about 45 years with most farmers having attended primary school, and belonging to farmers groups. There is an average of 17 years in terms of farming experience and land tenure system was based on secured renting.

**Table 1:** Socio-economic characteristics of respondents

| Household & social dynamic characteristics | Description | |
|---|---|---|
| | Nigeria | Ghana |
| Age | Mean = 42.86 | Mean = 45.70 |
| Educational level | Predominantly Quranic | Predominantly primary school |
| Membership of Farmer group | Predominantly members | Predominantly members |
| Membership of formal and informal clubs | Predominantly Yes | Predominantly Yes |
| Membership of traditional structures | Predominantly Yes | Predominantly Yes |
| Membership of localised structures | Predominantly Yes | Predominantly Yes |
| Shared norms among farmer groups | Predominantly Yes | Predominantly Yes |
| Extent of trust among farmers | Predominantly low | Predominantly high |
| Transport for easy network | Predominantly low | Predominantly high |
| Network with financial institutions for credit | Predominantly No | Predominantly Yes |
| Farming experience | Mean = 13 years | Mean = 17 years |
| Land tenure system | Predominantly Inheritance | Predominantly secured rent |
| Household size | Mean = 4.6 | Mean = 7.2 |

The results from the probit model in Table 2 show that the coefficients for 12 variables were significant each in Nigeria and Ghana. For Nigeria and Ghana respectively, these are age ($t = 4.12$, $p < 0.05$; $t = 7.20$, $p < 0.05$ ) educational level ($t = 2.77$, $p < 0.05$; $t = 2.32$, $p < 0.05$) ; membership of farmers groups($t = 1.93$, $p < 0.05$; $t = 2.57$, $p < 0.05$); membership of formal and informal clubs ($t = 2.29$, $p < 0.05$; $t = 9.63$, $p < 0.05$); membership of traditional structures ($t = 2.50$, $p < 0.05$; $t = 2.85$, $p < 0.05$); membership of formal localized structures ($t = 2.45$, $p < 0.05$; $t = 5.00$, $p < 0.05$); extent of trust among farmers ($t = 3.35$, $p < 0.05$; $t = -2.45$, $p < 0.05$ ); transport for easy network ($t = -1.73$, $p < 0.05$; $t = 4.24$, $p < 0.05$); farming experience ($t = 2.49$, $p < 0.05$; $t = 4.04$, $p < 0.05$), land tenure system ($t = -3.35$, $p < 0.05$; $t = -2.45$, $p < 0.05$); and household size ($t = 2.31$, $p < 0.05$; $t = 2.52$, $p < 0.05$). The sign for each coefficient is consistent with the expectation; as the probability of adoption of 'sawah' technology increases, age, educational level; membership of farmers groups; membership of formal and informal clubs; membership of traditional structures; membership of formal localized structures; extent of trust among farmers; transport for easy network; farming experience, land tenure system and household size increases. Anim and Mandleni (2010) found that all three types of social dynamics, bonding, bridging and linking affect technology adoption to some extent but bridging which includes trust shared norms and ownership of assets was the most predominant among farmers in Limpopo province in South Africa. Njuki et al (2008) found that bonding, bridging, and linking social capital all influence the adoption and use of different soil management options differently, a trend that might be similar for other agricultural technologies as well.

**Table 2:** Parameter estimates from Probit regression model

| | Nigeria | Ghana |
|---|---|---|
| Variables | Coeff./S.E. | Coeff./S.E |
| Age | 4.12 | 7.20 |
| Educational level | 2.77 | 2.32 |
| Membership of farmer group | 1.93 | 2.57 |
| Membership of formal and informal clubs | 2.29 | - 9.63 |
| Membership of traditional structures | 2.50 | 2.85 |
| Membership of localised structures | 2.45 | 5.00 |
| Shared norms among farmer groups | 1.34 | - 0.08 |
| Extent of trust among farmers | 3.35 | 2.45 |
| Transport for easy network | 1.73 | 4.24 |
| Network with financial institutions for credit | - 0.80 | - 0.02 |
| Farming experience | 2.49 | 4.04 |
| Land tenure system | - 3.35 | - 2.45 |
| Household size | 2.31 | 2.52 |
| Intercept | - 2.15 | - 18.00 |
| Pearson Goodness-of-Fit Chi Square | 110.02 | 301.22 |
| Df | 78 | 68 |
| P | 0.00 | 0.000 |

## Conclusion

The study has shown that social dynamics affect technology adoption under 'sawah' rice production. In both countries the adoption of 'sawah' rice technology was influenced by social dynamic variables such as membership of farmers groups; membership of formal and informal clubs; membership of traditional structures; membership of formal localized structures; extent of trust among farmers and transport for easy network. The disaggregation of the social dynamics variable has shown critical areas for the extension agents, 'sawah' staff and development agencies to concentrate in terms of the effect of social capital on adoption for the overall scaling out of the technology. The study recommends investments, especially by development organizations, in strengthening these different forms of social dynamics by supporting local kinship or community groups that generate social dynamics, promoting farmer access and links with external organizations that can act as sources of information and technologies for farmers, as well as links with other farmer associations and groupings from whom they can learn.

## References

Ameniya, T. 1981. Qualitative response models: A survey. *Journal of Economic Literature* 19: 1483-1536.

Anim F. D. K and Mandleni, B. 2010. Effect of social dynamics on technology adoption in urban, sub-urban and rural communities in the Limpopo province of South Africa. African Journal of Agricultural Research 51(17); 2310-2314

Claridge, T. 2007. *Social capital.* [online] URL: http://www.gnudung.com/.

Conley.T and C.Udry (2000) Learning About a New Technology: Pineapple in Ghana, Working Paper-Yale University.

Fashola, O.O, Oladele, O. I, Aliyu J and Wakatsuki, T. 2006. Dissemination of 'Sawah' Rice Technology to Farmers cultivating Inland valleys in Nigeria. Proceedings of the Asian Pacific Extension Network. 6-8th March 2006 Australia.

Fukuyama, F. 2004. *Social capital and development: course overview.* John Hopkins University, Baltimore, Maryland, USA.

Gajigo O. and Dennning G. 2010. Rice in Africa: Will imports continue to grow. Chapter 9 in the rice crisis: markets, policies and food security. David Dawe (ed). The Food and Agriculture Organization of the United Nations and Earth scan. Pp 163-190

Hirose. S and Wakatsuki T., 2002. *Restoration of Inland Valley Ecosystems in West Africa.* Association of Agriculture and Forestry Statistics, Tokyo, Japan.

Kabubo-Mariara, J., V. Linderhof, G. Kruseman, R. Atieno, and G. Mwabu. 2007. *Household welfare, investment in soil and water conservation, and tenure security: evidence from Kenya.* Poverty Reduction and Environmental Management (PREM)

Leonard, R., and J. Onyx. 2003. Networking through loose and strong ties: an Australian qualitative study. *Voluntas: International Journal of Voluntary and Nonprofit Organizations* 14(2):189–203.

Maddala, G. 1983. Limited dependent and qualitative variables in econometrics. New York: Cambridge University Press.

Njuki, J. M., M. T. Mapila, S. Zingore, and R. Delve. 2008. The dynamics of social capital in influencing use of soil management options in the Chinyanja Triangle of southern Africa *Ecology and Society* **13** (2) :9.

Oladele, O.I 2005. A Tobit analysis of propensity to discontinue adoption of agricultural technology among farmers in South-western Nigeria. Journal of Central European Agriculture 6 (3):249-254

Rogers E.M 2003. Diffusion of Innovations. Fifth Edition. New York: Free Press [3]Aker, J.C., Block , S., Ramachnadran, V and Timmer C.P 2010. West African Experience with the World Rice Crisis, 2007-2008. Chapter 8 in the rice crisis: markets, policies and food security. David Dawe (ed). The Food and Agriculture Organization of the United Nations and Earth scan. pp 143-162

Szreter, S., and M. Woolcock. 2004. Health by association? Social capital, social theory, and the political economy of public health. *International Journal of Epidemiology* 33:650–67

Woolcock, M., & Sweetser, A. T. 2007. *Social capital: the bonds that connect* Asian Development Bank (ADB), Manila, Philippines. [online]
URL: http://www.adb.org/ Fukuyama, F. 2004. *Social capital and development: course overview*. John Hopkins

Working Paper No. 06-06. PREM, Amsterdam, The Netherlands. [online]
URL:http://www.premonline.org/index.php?p=publications&a=show&id=120

Woolcock, M., and D. Narayan. 2000. Social capital: implications for development theory, research and policy. *World Bank Research Observations* 15(2):225–249.

Woolcock, M., & Sweetser, A. T. 2007. *Social capital: the bonds that connect* Asian Development Bank (ADB), Manila, Philippines. [online]
URL: http://www.adb.org/ Fukuyama, F. 2004. *Social capital and development: course overview*. John Hopkins University, Baltimore, Maryland, USA.

# The Effect of Green Revolution Technology during the Period of 1970-2003 on 'Sawah' Soil Properties in Java, Indonesia

DARMAWAN

*Department of Soil Science, Andalas University, Padang, West Sumatra, Indonesia*

**Abstract**

Many countries reported that the green revolution (GR) technology caused some adverse effects on agricultural lands, but there is no research on the effects of GR in Indonesia. In order to evaluate the effect of GR technology on 'sawah' soil in Indonesia, a comparative study between seed farms, where GR technology has been continuously applied, and non-seed farms was conducted in Java as a pioneer place of GR technology in Indonesia. Soil samples collected by Kawaguchi and Kyuma in 1970 and new samples taken in 2003 from the same sites or the sites close to the 1970 sampling were analyzed and compared. During the period of 1970- 2003 the land use pattern of 'sawah' in seed farms and non-seed farms were not changed but cultivation intensity increased. The result showed total carbon (TC) and total nitrogen (TN) contents significantly increased from 31.90 to 40.42 Mg $ha^{-1}$ and from 3.04 to 3.97 Mg $ha^{-1}$, respectively and were mostly accumulated in the surface soil layer. Differences in land management practices between seed farm and non-seed farm affected the change of TC and TN content in 0 - 20 cm soil layer during the period of 1970 to 2003. In seed farms, where rice had been planted in monoculture system, the TC and TN contents in the soil layer of 0-20 cm increased from 34.50 to 39.24 Mg $ha^{-1}$ and 3.16 to 3.95 Mg $ha^{-1}$, respectively. , mean soil pH and exchangeable sodium (Na) decreased from 6.90 ± 0.77 to 5.84 ± 0.90 and from 3.28 ± 2.76 to 1.67 ± 2.06 $kmol_c\ ha^{-1}$, respectively. Exchangeable acidity and available phosphorus (P) significantly increased from 9.32 ± 3.09 to 13.23 ± 3.72 $kmol_c\ ha^{-1}$ and from 136.62 ± 154.72 to 255.75 ± 292.41 kg $P_2O_5$ $ha^{-1}$, respectively. The average content of available Si decreased from 1512 ± 634 kg $SiO_2$ $ha^{-1}$ to 1230 ± 556 kg $SiO_2$ $ha^{-1}$ and from 6676 ± 3569 kg $SiO_2$ $ha^{-1}$ to 5894 ± 3372 kg $SiO_2$ $ha^{-1}$ in the 0-20 cm and 0-100 cm soil layers, respectively. Cultivation intensities' difference between seed farms planted with rice three times a year and non-seed farms rotated rice and upland crop seemed affected the changing rates of available Si within the study period. In the 0 - 20 cm soil layer, the average content of available Si decreased from 1646 ± 581 kg $SiO_2$ $ha^{-1}$ to 1283 ± 533 kg $SiO_2$ $ha^{-1}$ (- 22%) and from 1440 ± 645 kg $SiO_2$ $ha^{-1}$ to 1202 ± 563 kg $SiO_2$ $ha^{-1}$ (- 17%) in seed farms and non-seed farms, respectively. The demerit of 'sawah' system in Indonesia is mostly because of improper land management and imbalance nutrient input over long period of time.

**Key words:** chemical characteristics, green revolution, Java, 'sawah', seed farms, total carbon, total nitrogen.

## Introduction

Green Revolution (GR) is the term referring mainly to dramatic increases in cereal-grain yields in many developing countries beginning in the late of 1960s. The GR technologies are broadly classified into two majors categories. The first one is the breeding of new plant varieties; the second is the development of new agricultural techniques. The design of hybrid strains was motivated by a desire to, first, increase crop yield, and also to increase durability for transport and longevity for storage. The techniques refined and developed by the GR consisted of extensive use of chemical fertilizers, irrigation, pesticides and herbicides (FAO, 1984).

The GR technology has been criticized on several grounds, but the primary argument is an environmental problem. Runoff and leaching of fertilizer, pesticide and herbicide continue to be significant causes of environmental pollution, killing off beneficial soil microbes and other organisms; erosion of the soil; and loss of valuable trace elements (Pimentel, 1996). Some studies in India found that application of GR technology caused soil degradation and produced scarcity by reducing the availability of genetic diversity of crops (Singh, 2000). Similar conclusions were reported by researchers in Bangladesh (Rahman, 2003), China (Zhang *et al.*, 2003) and Latin America (Redclift, 1989). In case of Indonesia, GR technology was implemented in Java from 1966, by using the new high-yielding varieties (HYVs) of rice (i.e. IR-8) developed by the International Rice Research Institute (IRRI). This island was chosen as a pioneer place in adopting the GR technology, because it has some advantages as compared to the others. Indonesia had about 6 million hectares of irrigated 'sawah' and more than half was located in Java and as the centre of the country, Java was much easier to be monitored. The term 'sawah' refers to levelled rice field surrounded by bunds with inlet and outlet for irrigation and drainage (Wakatsuki *et al.*, 1998). To support the adoption of GR technology, Indonesian government established many research stations for rice (seed farm) throughout Java and supported them with good irrigation facilities, chemical fertilizers, pesticides and also qualified staff. Due to the abundance of cheap labour, mechanization under rice cultivation has not made much progress in Java and Indonesia as a whole. The main function of seed farm was to bridge technology transfer from researchers (mostly from IRRI) to farmers and also as a food security buffer for the country (Indonesian Ministry of Agriculture, 1995).

The GR was not a once-and-for-all change in technology. In the beginning of the period, the new rice cultivation systems consisted of new HYVs of rice, application of chemical fertilizers and pesticides was done in the seed farms. Java had more than 20 seed farms, spreading all over the island (Indonesian Ministry of Agriculture, 1995). Implementation of GR technology caused a lot of changes in rice cultivation systems in Java. Differences in land management practices might have affected soil chemical properties. In seed farm, where rice has been planted continuously using high amounts of chemical fertilizers the trend was different when compared with non-seed farm where farmers used low amounts of chemical fertilizers but in rotation. Kawaguchi and Kyuma (1977) noted that in 1970, all seed farms in Java were practicing GR technology using HYVs of rice, chemical fertilizers and pesticides and produced about 2.5 Mg $ha^{-1}$ of husked rice on average. The productivity of seed farms was almost two folds compared with non-seed farms, where local varieties were planted with traditional management ways. However, since the GR technology started to be adapted to non-seed farms, this wide gap of productivity was gradually eliminated and both of them have been able to produce 5.5 Mg $ha^{-1}$ per cropping season (Indonesian Ministry of Agriculture, 1995).

Although seed farms and non-seed farms were located in one island, their cultivation and land management practices were quite different. Indonesia government supplied seed farms with all their needs for rice cultivation. In order to ensure food security, most of the seed farms planted rice over the whole year, using modern cultivation management systems. On the other hand, rice cultivation in non-seed farms was affected by the non availability of water, and application of chemical fertilizers and pesticides depending on the farmers' budget. Most of the non-seed farms were cultivated by rented farmers that made it difficult to track the history of chemical fertilizers application on those sites. However, according to Lansing *et al.*, (2001), application rates of chemical fertilizers by Java's and Bali's farmers are much lower than government recommendation. During the less rainfall season, from April to September, most non-seed farms planted upland crops, dominated by vegetables such as soybean, green bean, peanuts, chili, maize, cassava and sugarcane in some crop rotation patterns (Nair, 1985).

Differences in cultivation and land management systems between seed farms and non-seed farms might also have affected 'sawah' soil properties. The purposes of this study are to evaluate the effects of GR technology on the changes of 'sawah' soil during the period of 1970 and 2003, in relation to differences in soil properties.

## Materials and Methods

*Description of study area and sampling sites*

Java is the smallest among the five biggest islands in Indonesia archipelago. It lies between 05°52'34" S to 08°46'46" S and 105°12'40" E to 114°35'38" E. Although the total land area of this island is just 132,187 $km^2$, which is about 7 percent of the total land area of Indonesia, more than half of Indonesian people live here. Figure 1 shows the study area and distribution of sampling sites both in 1970 and 2003 throughout the island. Most of the sampling sites are located in the northern part along the coastal plain, because the southern part of Java is mountainous and difficult to access. Tables 1 gives the brief information on soil and land use pattern both in 1970 and 2003, including the general description in each sampling sites.

The present land use patterns in each seed farm and non-seed farm were almost similar compared to 1970, but cultivation intensity increased. Most of the seed farms grew rice three times a year and non-seed farms planted with rice and upland crops in rotation patterns. Although rice is still the major crop in Java, the area of 112,000 hectares 'sawah' decreased during the period 1984-2000 or about 7000 ha every year (Verburg *et al.*, 1999). Among 46 sampling sites in 1970, four of them (site number 2, 4, 5, and 40) were not sampled in 2003 because land use changed to non-agricultural purposes and two sites (number 15 and 30) changed to other crop cultivation were also excluded in this study. For the remaining 40 sites in 2003, twenty-five of them were identified as the original sites with 1970's (Table 1) consulting with the description sheets made by Kawaguchi and Kyuma and/or information from the landowners and old farmers near the sites. Since 15 sites could not be confirmed as the original sites due to land use changes and lack of information, soil was collected from the closest site to 1970's sampling areas. Among 40 sites in 2003, twenty-two sites were located in non-seed farm 'sawah' and the other eighteen were in seed farms. Inceptisols and Vertisols were the main two soil types in the sites, dominating 24 and 14 locations, respectively. The other two, number 8 and 10 belonged to Ultisols and Alfisols (Table 1).

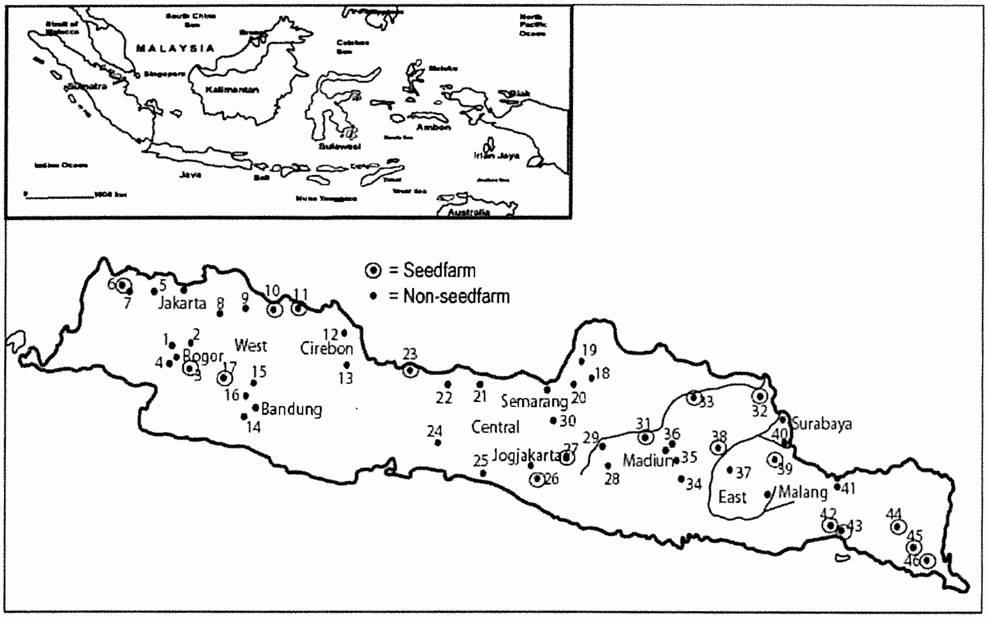



**Figure 1.** The map of Indonesia showing the Java Island with the main cities and distribution of sampling sites both in 1970 and 2003

*Soil sampling and interview*

The study used soil samples taken by Kawaguchi and Kyuma in 1970 as references. These soil samples had been air dried and kept in sealed plastic bottles in a storage room. The second sampling was done in April and December 2003 from the same or closest to original sites in 1970. Soil samples were collected from each horizon in a profile at the respective sites by using 100 $cm^3$ core samplers to determine the bulk density of soil. Composite soil samples from the each horizon were also collected as well for chemical analyses. To ensure the reliability of 1970 soil samples, our analytical data and the original data from Kyoto University was compared. Both analytical results were found to be very similar with less than 5% difference (data not published).

In order to get the latest information about the changes in rice cultivation systems and productivity in seed farms and non-seed farms during the period of 1970 and 2003, we interviewed seed farms staff and farmers on the respective sites assisted by the counterparts as interpreters.

*Laboratory analyses.*

***Total Carbon and Nitrogen.*** Air-dried soil samples were ground and passed through a 2 mm sieve and stored in plastic boxes for laboratory analyses. Soil samples from both 1970 and 2003 were treated similarly. A total of 349 soil samples (165 for 1970 and 184 for 2003) were analyzed for total carbon (TC) and total nitrogen (TN) contents. Finely ground soil samples were oven dried at 80°C for about 24 hours. Total carbon and nitrogen were determined by dry combustion method (Nelson and Sommers, 1982) using Yanaco CN Corder Model MT-700 (Yanagimoto MFG. Co. Ltd., Kyoto, Japan).

***Available Nitrogen.*** Six grams of soil in a glass tube was submerged with distilled water and covered with rubber stopper. These tubes were incubated at 30 °C for 28 days. After incubation, the inorganic nitrogen in soil was extracted with 2 M KCl and the content was determined by steam distillation method with MgO and Devarda alloy (JSSPN, 1986).

***Bulk density.*** Bulk density is necessary for converting carbon and nitrogen contents on a weight basis to content on the volume basis (e.g. Mg $ha^{-1}$ to the 100 cm depth). Bulk density of a soil was calculated by using the sample in a 100 $cm^3$-core. After oven drying at 105°C for about 72 hours, the weight of soil per core sample volume (100 $cm^3$) was measured. The bulk density values in 2003 were used to calculate the carbon and nitrogen contents for both samples taken in 1970 and 2003, since the bulk density of 1970's samples was not determined.

***Chemical properties of soils.*** The air-dried soil samples were ground and passed through a 2-mm sieve. Soil pH was measured using the glass electrode method with a soil: water ratio of 1:2.5 (IITA, 1979; Mclean 1982). Exchangeable acidity was determined by first extracting with 1 M KCl and titrating with NaOH (Mclean, 1965). Exchangeable base cations (Ca, Mg, K and Na) were extracted by 1 M neutral ammonium acetate (Thomas, 1982) and then exchangeable Ca and Mg were determined by using Inductively Coupled Plasma-Atomic Emission Spectroscopy (Shimadzu ICPS 2000) and exchangeable K and Na determined by Atomic Absorption Spectrophotometer (Shimadzu AS 680). Effective cation exchange capacity (eCEC) represents the sum of the amount of exchangeable bases and the exchangeable acidity. Available P was extracted by Bray 2 method and the content was determined by colorimetry with UV/VIS Spectrophotometer (Jasco V-530, Tokyo-Japan) (Bray and Kurtz, 1945).

*Calculation and statistical analyses*

***The calculation method of soil carbon and nitrogen content.*** The depths of the identical horizons were not perfectly the same but very similar in the 1970 and 2003 (Figure 2 and 3). The carbon and nitrogen contents were estimated on per hectare basis using the equation below (Ali *et al.*, 1997). For an individual profile with *n* horizons, the calculation of the total carbon and nitrogen contents on a volume basis was as follow:

$$\sum = nipiPiDiTd1 \qquad (1)$$

where, $Td$ = total content of carbon or nitrogen (Mg $ha^{-1}$) at a depth $d$, $pi$ = bulk density (Mg $m^{-3}$) of horizon $i$, $=Pi$proportion of carbon or nitrogen (g $kg^{-1}$) in horizon $I$, $Di$ = thickness of the horizon *(cm)*. Similar calculations were also applied for other soil characters.

**Statistical analyses.** To examine the effect of land management differences on the change patterns, all data was analyzed by SPSS (Version 11.0 for Windows). Paired-samples T-test was used for comparing means of TC and TN contents using land management differences referring to seed farm and non-seed farm as blocks

**Results and Discussion**

*Change in carbon and nitrogen stocks in 'sawah' soil during the period of 1970 - 2003.*
Table 2 describes the mean and changes in TC and TN contents in each site. Change in TC content ranged from -29.5 % (site number 8) to 137.9 % (site number 27), but at most sites change was greater than 25%. Change in TN content ranged from - 26.3 % (site number 45) to 121.3 % (site number 24), with the change at most sites also being greater than 25 %. Figure 2 and 3 show the profile distributions of TC and TN contents in 1970 and 2003 in seed farms and non-seed farms, respectively. TC and TN contents highly varied among the sites. Mean TC content for seed farms sites increased throughout the soil profile from $8.23 \pm 5.06$ g $kg^{-1}$ to $9.81 \pm 5.01$ g $kg^{-1}$ during the period of 1970 to 2003; while in non-seed farms TC changed from $8.37 \pm 5.11$ g $kg^{-1}$ to $10.27 \pm 6.26$ g $kg^{-1}$. Mean values of TN content in seed farms increased from $0.85 \pm 0.46$ g $kg^{-1}$ to $1.05 \pm 0.46$ g $kg^{-1}$ and $0.91 \pm 0.42$ g $kg^{-1}$ to $1.04 \pm 0.52$ g $kg^{-1}$ in non-seed farms sites.

**Table 1.** Descriptions of sampling sites and land use pattern during the period between 1970 and 2003 Java, Indonesia.

| Sampling Code | Location name | GPS reading South | GPS reading East | Elevation | Land use pattern 1970§ | Land use pattern 2003 | USDA Taxonomy | Note |
|---|---|---|---|---|---|---|---|---|
| In-1 | Kedung Halang, Bogor | S 06°33'0.6.3" | E 106°48'26.4" | 213 meter | rice-upland crop | upland crop | Aeric Epiaquepts | B-NS |
| In-3 | Bendungan Ciawi, Bogor | S 06°39'43.2" | E 106°51'40.4" | 529 meter | rice-rice | rice-rice-upland crops | Aeric Epiaquepts | A-SF |
| In-6 | Kebun Percobaan Singamerta, Ciruas | S 06°07'14.7" | E 106°14'36.5" | 26 meter | rice-rice | rice-rice-rice | Typic Epiaquepts | A-SF |
| In-7 | Petung Sentul, Kragilan Serang | S 06°07'52.0" | E 106°16'16.5" | 31 meter | rice-upland crop | rice-rice-upland crops | Typic Halaquepts | B-NS |
| In-8 | Pasir Gombong Lemahabang, Bekasi | S 06°07'52.0" | E 106°16'16.5" | 31 meter | rice-upland crop | rice-rice-upland crops | Typic Kanhapludults | B-NS |
| In-9 | Palawad, Karawang | S 06°17'30.0" | E 107°21'13.6" | 32 meter | rice-rice | rice-rice-upland crops | Vertic Epiaquepts | B-NS |
| In-10 | Balitpa Sukamandi, Subang | S 06°21'27.1" | E 107°38'38.2" | 31 meter | rice-rice | rice-rice-rice | Aeric Endoaqualfs | A-SF |
| In-11 | LPPP Pusakanegara, Subang | S 06°16'43.0" | E 107°52'26.6" | 22 meter | rice-rice | rice-rice-rice | Vertic Epiaquepts | A-SF |
| In-12 | Sudikampiran, Sliyeg Indramayu | S 06°29'00.7" | E 108°22'44.4" | 22 meter | rice-rice | rice-rice-upland crop | Vertic Endoaquepts | B-NS |
| In-13 | Sampora, Cilimus Kuningan | S 06°51'32.3" | E 108°29'26.1" | 452 meter | rice-upland crop | rice-rice-upland crops | Typic Dystropepts | B-NS |
| In-14 | Pamoyanan, Ketapang Bandung | S 06°00'08.5" | E 107°33'10.1" | 685 meter | rice-rice | rice-rice-upland crops | Typic Endoaquepts | B-NS |
| In-16 | Warungkaweni Cipageran, Cimahi | S 06°51'17.4" | E 107°32'54.1" | 825 meter | rice-upland crop | upland crop | Mollic Fragiaquepts | B-NS |
| In-17 | LPPP Ciheya, Ciranjang, Cianjur | S 06°50'15.7" | E 107°16'26.5" | 209 meter | rice-rice | rice-rice-rice | Aeric Epiaquerts | A-SF |
| In-18 | Medini, Undaan Kudus | S 06°55'04.6" | E 110°47'43.7" | 22 meter | rice-upland | rice-rice-rice/upland crops | Vertic Endoaquepts | A-NS |
| In-19 | Mayong Lor, Mayong Jepara | S 06°45'41.7" | E 110°45'08.4" | 25 meter | rice-upland crop | rice-rice-upland crops | Aquic Eutropepts | B-NS |
| In-20 | Katonsari, Demak | S 06°54'42.2" | E 110°36'59.0" | 17 meter | rice-upland crop | rice-rice-upland crops | Typic Calciaquepts | A-NS |
| In-21 | Kartoharjo, Buaran Pekalongan | S 06°55'19.5" | E 109°40'16.5" | 14 meter | rice-upland crop | rice-rice-upland crops | Aeric Epiaquerts | A-NS |
| In-22 | Sirandu, Pemalang | S 06°54'11.5" | E 109°22'53.2" | 25 meter | rice-upland crop | rice-upland crop | Aeric Epiaquerts | A-NS |
| In-23 | Seedfarm Bulakamba, Brebes | S 06°21'27.1" | E 108°57'07.0" | 11 meter | rice-rice | rice-rice-upland crops | Typic Natraquerts | A-SF |
| In-24 | Bojong, Purbolinggo | S 07°24'44.4" | E 109°22'31.0" | 45 meter | rice-upland crop | rice-rice-upland crops | Typic Endoaquepts | B-NS |
| In-25 | Lajer Ambal, Kebumen | S 07°44'45.6" | E 109°43'28.8" | 22 meter | rice-upland crop | rice-rice-upland crops | Vertic Endoaquepts | A-NS |
| In-26 | Seed farm Wonocatur, Bantul | S 07°48'02.5" | E 110°24'27.3" | 118 meter | rice-rice | rice-rice-rice | Aeric Epiaquepts | A-SF |
| In-27 | Humo Seed farm, Semangkak | S 07°42'29.5" | E 110°35'51.6" | 159 meter | rice-rice | rice-upland crop | Aeric Epiaquepts | A-SF |
| In-28 | Jumapolo, Karanganyar | S 07°42'29.5" | E 111°00'04.8" | 339 meter | rice-upland crop | rice-rice-upland crops | Typic Dystrustepts | B-NS |
| In-29 | Papaban, Tasikmadu Karanganyar | S 07°42'38.2" | E 111°17'17.2" | 182 meter | rice-upland crop | rice-rice-rice/upland crops | Typic Epiaquerts | A-NS |
| In-31 | LPPP Ngale, Paron Ngawi | S 07°24'37.6" | E 111°22'18.3" | 68 meter | rice-rice | rice-rice-upland crops | Typic Calciaquerts | A-SF |
| In-32 | BPMD Sukodadi, Lamongan | S 07°05'28.0" | E 112°19'41.7" | 26 meter | rice-upland crop | rice-rice-upland crops | Typic Epiaquerts | A-SF |
| In-33 | BPMD Brenggolo, Bojonegoro | S 07°07'39.4" | E 111°45'21.1" | 37 meter | rice-upland crop | rice-rice-upland crops | Aeric Endoaquerts | B-SF |
| In-34 | Kresek Wungu, Madiun | S 07°41'47.9" | E 111°36'58.0" | 277 meter | rice-upland crop | rice-rice-upland crops | Aeric Epiaquepts | B-NS |
| In-35 | Banjarsari, Dagangan Madiun | S 07°41'01.5" | E 111°35'49.2" | 214 meter | rice-upland crop | rice-rice-rice | Typic Calciaquerts | B-NS |
| In-36 | Patang, Nglames Madiun | S 07°35'31.1" | E 111°32'51.6" | 74 meter | rice-rice | rice-rice-upland crops | Typic Epiaquerts | A-NS |
| In-37 | Pelem, Pare Kediri | S 07°45'58.8" | E 112°10'02.4" | 113 meter | rice-upland crop | rice-rice-upland crops | Typic Epiaquepts | B-NS |
| In-38 | Seed farm Waung, Baron Nganjuk | S 07°35'51.7" | E 112°02'03.3" | 56 meter | rice-upland crop | rice-rice-upland crops | Aeric Epiaquepts | A-SF |
| In-39 | LPPP Mojosari, Mojokerto | S 07°30'27.9" | E 112°31'36.6" | 33 meter | rice-upland crop | rice-rice-rice | Aeric Epiaquepts | A-SF |
| In-41 | Maron Kulon, Maron Probolinggo | S 07°50'48.8" | E 113°21'02.2" | 78 meter | rice-upland crop | rice-rice-rice/upland crops | Typic Epiaquepts | A-NS |
| In-42 | Labruk Kidul, Lumajang | S 08°08'45.4" | E 113°12'18.6" | 89 meter | rice-rice | rice-rice-rice/upland crops | Typic Epiaquerts | A-SF |
| In-43 | BPMD Yasowilangun, Lumajang | S 08°12'58.8" | E 113°18'06.7" | 30 meter | rice-upland crop | rice-rice-rice | Aeric Endoaquerts | A-SF |
| In-44 | Balai benih Srimurui, Arjasa Jember | S 08°07'10.4" | E 113°44'47.9" | 181 meter | rice-upland crop | rice-rice-rice | Fluvaquentic Epiaquep | A-SF |
| In-45 | LPPP Genteng, Banyuwangi | S 08°22'47.4" | E 114°08'37.0" | 159 meter | rice-rice | rice-rice-rice/upland crops | Aeric Epiaquepts | A-SF |
| In-46 | Seed farm Sukorejo, Banyuwangi | S 08°29'30.7" | E 114°08'13.3" | 93 meter | rice-upland crop | rice-rice-rice | Typic Calciaquerts | A-SF |

Note: A = original sites; B = close to original sites; SF = seedfarms; NS = non-seedfarms; §= data from Kawaguchi and Kyuma (1977)

**Table 2.** Changes in TC and TN (Mg ha$^{-1}$) content in topsoil layer of each sampling sites in Java, Indonesia (1970-2003) and Bangladesh (1967-1995).

| Profile no./location | Total Carbon (Mg ha$^{-1}$) | | | Total Nitrogen (Mg ha$^{-1}$) | | | Bulk density |
|---|---|---|---|---|---|---|---|
| | 1970[a] | 2003[b] | % change | 1970[a] | 2003[b] | % change | (Mg m$^{-3}$) |
| 1. Kedunghalang Bogor | 39.29 | 39.15 | -0.4 | 3.77 | 3.88 | 2.8 | 1.11 |
| 3. Bendungan Ciawi | 43.93 | 48.55 | 10.5 | 4.37 | 5.27 | 20.5 | 1.15 |
| 6. Singamerta Ciruas | 38.70 | 37.76 | -2.4 | 4.01 | 4.20 | 4.6 | 1.18 |
| 7. Petung Sentul | 11.22 | 12.61 | 12.4 | 1.10 | 1.60 | 45.9 | 1.10 |
| 8. Pasir Gombong | 40.41 | 28.50 | -29.5 | 1.94 | 3.15 | 62.7 | 1.21 |
| 9. Palawad Karawang | 48.14 | 39.95 | -17.0 | 4.01 | 4.09 | 2.0 | 1.18 |
| 10. Balitpa Sukamandi | 24.93 | 34.74 | 39.4 | 3.15 | 3.80 | 20.7 | 1.21 |
| 11. LPPP Pusakanegara | 41.33 | 50.33 | 21.8 | 3.28 | 5.38 | 64.2 | 1.26 |
| 12. Sudikampiran Sliyeg | 20.09 | 29.13 | 45.0 | 3.72 | 3.25 | -12.7 | 1.24 |
| 13. Sampora Cilimus | 21.18 | 39.00 | 84.1 | 2.86 | 3.92 | 37.3 | 1.19 |
| 14. Pamoyanan Ketapang | 52.92 | 58.63 | 10.8 | 5.80 | 5.63 | -2.9 | 1.26 |
| 16. Warungkaweni Cipageran | 38.56 | 48.91 | 26.9 | 3.81 | 4.86 | 27.7 | 1.19 |
| 17. LPPP Ciheya | 40.25 | 45.62 | 13.4 | 4.13 | 4.58 | 10.9 | 1.29 |
| 18. Medini Undaan, Kudus | 30.21 | 71.63 | 137.1 | 4.10 | 6.03 | 47.1 | 1.28 |
| 19. Mayong Lor Jepara | 27.82 | 28.33 | 1.8 | 2.68 | 2.77 | 3.2 | 1.22 |
| 20. Katonsari Demak | 29.97 | 54.43 | 81.6 | 4.57 | 5.23 | 14.5 | 1.27 |
| 21. Kartoharjo Buaran | 20.99 | 46.65 | 122.2 | 2.56 | 4.24 | 65.6 | 1.28 |
| 22. Sirandu Pemalang | 24.70 | 38.47 | 55.8 | 2.02 | 4.08 | 102.2 | 1.26 |
| 23. Bulakamba Brebes | 27.90 | 33.54 | 20.2 | 2.05 | 4.10 | 100.0 | 1.28 |
| 24. Bojong Purbolinggo | 33.92 | 70.05 | 106.5 | 2.95 | 6.53 | 121.3 | 1.22 |
| 25. Lajer Ambal, Kebumen | 35.70 | 46.36 | 29.9 | 2.86 | 4.29 | 50.2 | 1.19 |
| 26. Wonocatur Bantul | 18.64 | 18.88 | 1.3 | 1.65 | 2.51 | 52.2 | 1.18 |
| 27. Semangkak Klaten | 18.41 | 43.79 | 137.9 | 2.12 | 4.67 | 119.7 | 1.18 |
| 28. Jumapolo Karanganyar | 19.72 | 26.21 | 32.9 | 1.62 | 2.82 | 73.5 | 1.16 |
| 29. Tasikmadu Karanganyar | 13.46 | 30.67 | 127.9 | 1.78 | 3.26 | 83.2 | 1.27 |
| 31. LPPP Ngale | 34.58 | 48.00 | 38.8 | 2.66 | 3.75 | 40.8 | 1.33 |
| 32. BPMD Sukodadi | 32.23 | 31.03 | -3.7 | 1.83 | 2.69 | 46.8 | 1.31 |
| 33. BPMD Brenggolo | 46.70 | 58.05 | 24.3 | 3.61 | 4.91 | 35.9 | 1.29 |
| 34. Krese Wungu | 38.84 | 45.64 | 17.5 | 3.74 | 4.23 | 12.9 | 1.22 |
| 35. Banjarsari Dagangan | 30.99 | 39.34 | 27.0 | 1.78 | 3.61 | 102.8 | 1.27 |
| 36. Patang, Nglames | 34.27 | 60.19 | 75.6 | 3.02 | 5.08 | 68.1 | 1.26 |
| 37. Pelem Paree | 16.42 | 21.65 | 31.8 | 1.83 | 2.04 | 11.1 | 1.19 |
| 38. Waung Baron Nganjuk | 27.38 | 37.32 | 36.3 | 2.60 | 3.61 | 39.2 | 1.18 |
| 39. LPPP Mojosari | 23.13 | 24.25 | 4.9 | 2.12 | 2.46 | 15.8 | 1.18 |
| 41. Maron Kulon | 26.14 | 34.75 | 32.9 | 2.18 | 3.00 | 37.7 | 1.21 |
| 42. Labruk Kidul Lumajang | 37.00 | 38.85 | 5.0 | 3.50 | 4.28 | 22.4 | 1.25 |
| 43. BPMD Yosowilangun | 50.55 | 46.60 | -7.8 | 5.33 | 4.69 | -12.0 | 1.27 |
| 44. Srimurni Arjasa | 27.38 | 32.26 | 17.8 | 2.60 | 3.32 | 27.9 | 1.18 |
| 45. LPPP Genteng | 47.34 | 34.60 | -26.9 | 4.88 | 3.60 | -26.3 | 1.22 |
| 46. Sukorejo Bangorejo | 40.57 | 42.20 | 4.0 | 3.02 | 3.26 | 7.8 | 1.26 |
| Mean Java, Indonesia | 31.9 | 40.4*** | 26.7 | 3.0 | 3.96*** | 30.6 | 1.22 |
| Mean Bangladesh § | 23.7 | 21.1 | -11.0 | 2.5 | 2.2 | -11.8 | 1.45 |

[a] Calculated base on the bulk density in 2003 [b] Paired samples T-test; *** significant at 0.001 level

§ data from Ali et al. (1997)

Variations in changing rates of TC and TN content among the sampling sites could have been affected by management practices in each site. For instance, although site number 45 was a seed farm that was planted with rice over the whole year, TC content decreased by - 26% while TC content at site 18 that was non-seed farm increased by more than 100 %. This disparity might be due to the differences in harvesting practices between these two sites. At site 45, whole rice straw was always taken away from the 'sawah' by farmers to feed their cattle. On the other hand farmers at site 18 only took out the rice grain and left the plant residues decomposed in the field, which was the typical harvesting management practice in Java. Lansing *et al.*, (2001) indicated that most of Java's and Bali's farmers thresh the rice stalks in situ and remove only the grain, leaving the rest of the plant to be ploughed under or burnt.

The application of GR technology in Java caused the accumulation of TC and TN in 'sawah' soils with a changing rate of about 30% between 1970-2003. On the other hand, within a similar period, Bangladesh decreased by -11% for these two parameters (Table 2). The differences in changing rate of 'sawah' productivity in these two regions could be a reason for these results. During the period of 1966 to 1996, rice production increased from 1.8 Mg $ha^{-1}$ to 4.5 Mg $ha^{-1}$ (150%) in Indonesia, which was much higher compared with that in Bangladesh which recorded a marginal increase (65%) from 1.7 Mg $ha^{-1}$ to 2.8 Mg $ha^{-1}$ (Otsuka, 2000). The farming systems were also different. Rice cultivation was predominant in Indonesia, which might accumulate more organic matter as main resources of carbon and nitrogen in the soils compared with those in Bangladesh, where the upland crop dominated (Ali *et al.*, 1997). The amount of carbon stored in 'sawah' system is greater than upland because of different biochemical processes and mechanisms mainly caused by the presence of flooded water in 'sawah' (Guo and Lin, 2001). The fraction of remaining carbon from total quantities added is higher under flooding than under non-flooding conditions. Both decomposition and mineralization rates of organic matter in anaerobic condition are considerably retarded compared with those under aerobic condition. Therefore, 'sawah' has a tendency to enhance carbon and nitrogen accumulation in the soil (Zhang and He, 2004).

*Vertical distribution of carbon and nitrogen under different land use management*

Figures 2 and 3 show the effect of GR on the profile distribution of TC and TN contents in respective sites in seed farms and non-seed farms between 1970 and 2003. It was clear that the changes and accumulation of TC and TN contents in each site were predominantly found within the topsoil. In the deeper layers, TC and TN contents of soils in 1970 were not so different compared with samples collected in 2003 for both seed farms and non-seed farms. This means that differences in land use management practices did not affected TC and TN distribution in the deeper layers of these soils. The International Rice Research Institute (IRRI-1986) and Zhang *et al.*, (2003) reported that intensive use of 'sawah' would form compacted and impermeable layer below the puddle layer that will protect the movement of nutrient and water to the deeper soil layer. This accounted for TC and TN accumulation in mostly the topsoil. The greater accumulation of TC and TN in top soil layers could be explained by increased input of plant residues, reduced decomposition rate of organic matter and increased nitrogen fixation in the 'sawah' systems (Kundu and Ladha, 1995; Roger and Ladha, 1992).

There were no significant differences both in TC and TN distribution between Inceptisols and Vertisols. The long-term intensive use of 'sawah' already eliminated the differences in the original characteristic of Inceptisols and Vertisols in 1970. Vertisols are clayey soil characterized by the ability to form deep cracks under dry conditions and the surface soils rich in nutrients move down through the crack (Kirby *et al.*, 2000 and Tomar *et al.*, 1996), so that TC and TN were expected to be distributed more in the deeper horizons in Vertisols as compared to the other soil type. However, under 'sawah' condition it seemed that phenomenon did not occur frequently. As shown in Table 1, most Vertisols were found in seed farms sampling sites, where intensive rice cropping kept the soil always in wet condition and probably prevented Vertisols from forming deep cracks and therefore prevented the movement of nutrients including carbon and nitrogen to the deeper horizon.

*Effects of land management on the changes of total carbon and nitrogen.*

Table 3 shows how differences in management practice bewteen seed farms and non-seed farms influenced the changing rates of TC and TN contents in 0–20 and 0–100 cm soil layers. The mean value of TC in seed farms increased from 34.50 to 39.24 Mg ha$^{-1}$ (13.7% change) in the 0–20 cm soil layer and from 92.68 to 112.83 Mg ha$^{-1}$ (21.7% change) in the 0–100 cm soil layer, respectively. Within the same period TC content in non-seed farms significantly increased from 29.77 to 41.37 Mg ha$^{-1}$ and from 79.6 to 114.8 Mg ha$^{-1}$ in 0 – 20 cm and 0 – 100 cm the soil layer, respectively, with a relative change of about 40% in both soil layers. In the case of TN, seed farms and non-seed farms increased from 3.16 to 3.95 Mg ha$^{-1}$ (25.0% change) and 2.94 to 3.98 Mg ha$^{-1}$ (35.4% change) in the 0–20 cm soil layer, which was significantly different at 0.01 and 0.001 levels, respectively. And within the 0–100 cm soil layer, TN content changed by 28% at both sites (Table 3). Although, TN contents in seed farms were much higher as compared to those in non-seed farms in 1970, they were found to be similar in 2003 (Table 3).

Kawaguchi and Kyuma (1977) reported that in 1970 seed farms and non-seed farms sites produced rice husk about 2.5 Mg ha$^{-1}$ and 1.5 Mg ha$^{-1}$, respectively, but from 1990's both of them have been able to produce about 5.5 Mg ha$^{-1}$ of rice husk per cropping season (Indonesian Ministry of Agriculture, 2001). It means that the increasing rate of rice productivity during the period between 1970 and 2003 in non-seed farms was more than three folds, which was much higher than that in seed farms. The increase of rice productivity probably related with the increase of TC and TN contents in both sites. Increase of the rice production augmented the amount of plant residues such as straw, leaf and root remained in 'sawah' field, especially in non-seed farms in which residues were usually left in the field. This might have contributed to the increase of TC and TN in both seed farms and non-seed farms. Tiessen *et al.*, (1994) reported that increase of plant production would increase the organic matter input to the soils as a major source of carbon and nitrogen in the soils.

**Table 3.** Changes in TC and TN (Mg ha$^{-1}$) content in 0–20 cm and 0–100 cm soil layer in seed farms and non-seed farms (1970 - 2003) in Java, Indonesia.

Total Carbon (Mg ha$^{-1}$)

| | Seedfarm | | | | Non-Seedfarm | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 - 20 cm | | 0 - 100 cm | | 0 - 20 cm | | 0 - 100 cm | |
| | 1970 | 2003 | 1970 | 2003 | 1970 | 2003 | 1970 | 2003 |
| *n* | 18 | 18 | 18 | 18 | 22 | 22 | 22 | 22 |
| mean | 34.50 | 39.24 | 92.68 | 112.83 | 29.77 | 41.37 | 79.60 | 114.86 |
| SD | 9.95 | 9.70 | 39.47 | 40.91 | 10.88 | 15.12 | 28.07 | 40.50 |
| mean change | | 4.74 | | 20.15 | | 11.60 | | 35.26 |
| % change | | 13.7 | | 21.7 | | 39.0 | | 44.3 |
| *T*-test | | * | | *** | | *** | | *** |

Total Nitrogen (Mg ha$^{-1}$)

| | Seedfarm | | | | Non-Seedfarm | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 - 20 cm | | 0 - 100 cm | | 0 - 20 cm | | 0 - 100 cm | |
| | 1970 | 2003 | 1970 | 2003 | 1970 | 2003 | 1970 | 2003 |
| *n* | 18 | 18 | 18 | 18 | 22 | 22 | 22 | 22 |
| mean | 3.16 | 3.95 | 9.34 | 12.03 | 2.94 | 3.98 | 8.93 | 11.44 |
| SD | 1.07 | 0.89 | 4.01 | 4.10 | 1.15 | 1.24 | 3.16 | 3.30 |
| mean change | | 0.79 | | 2.69 | | 1.04 | | 2.51 |
| % change | | 25.0 | | 28.8 | | 35.4 | | 28.1 |
| *T*-test | | ** | | *** | | *** | | *** |

*n* = number of sampling sites
Significant level: * ? 0.05 < ** ? 0.01 < *** ? 0.001

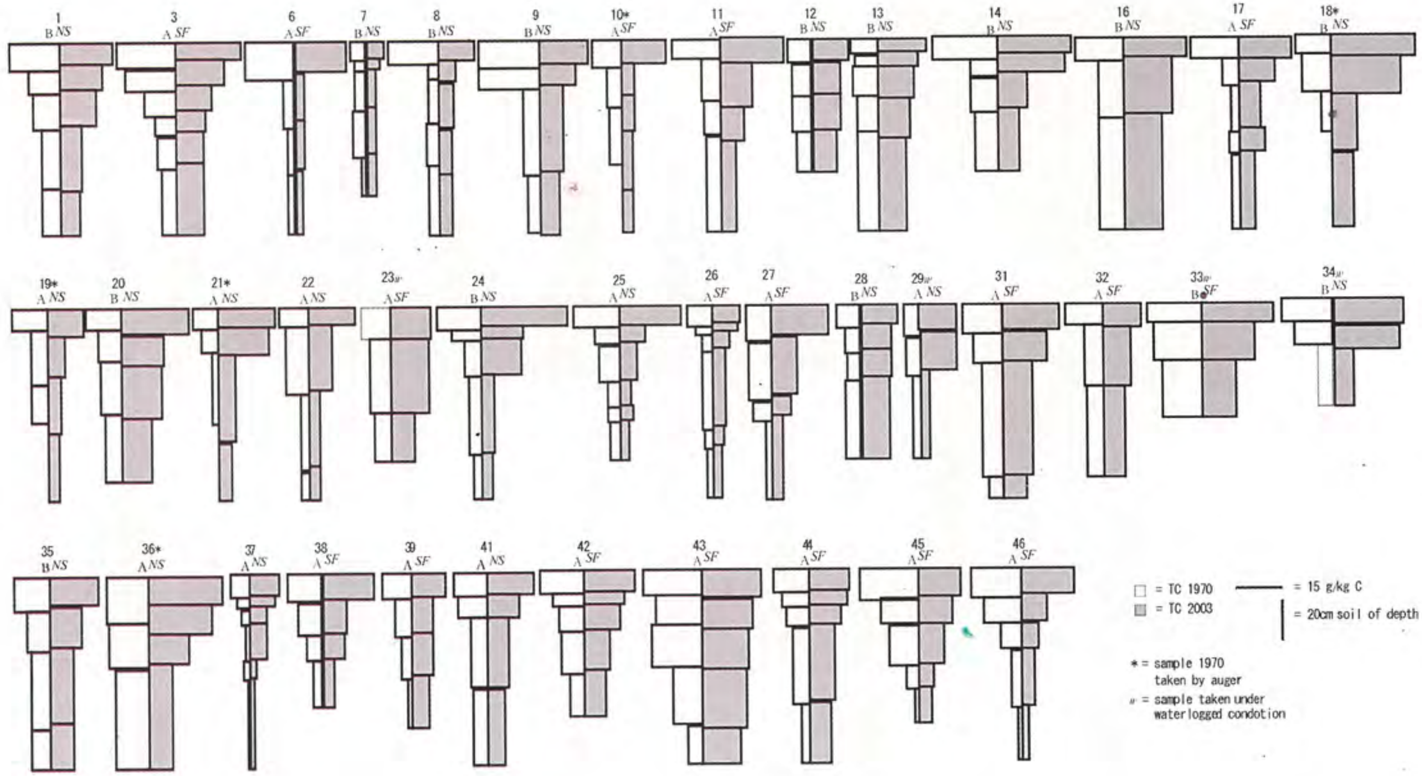



**Figure 2.** The effect of GR technology application on the profiles distribution of TC (g kg$^{-1}$) content of soil in seed farm (*SF*) and non-seed farm (*NS*) sites in Java Island, Indonesia (1970-2003). A = original sites; B = closest to original sites.

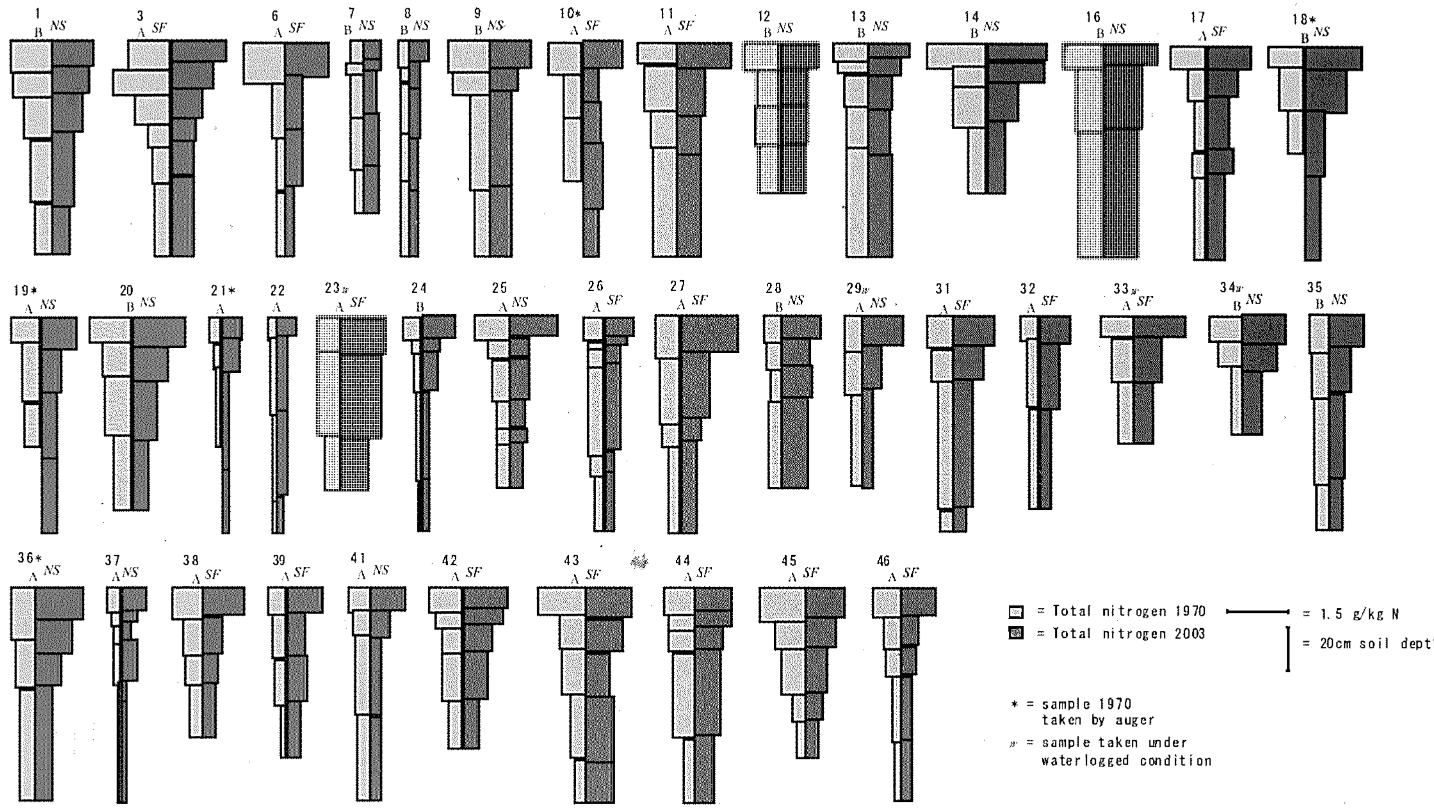



**Figure 3.** The effect of GR technology application on profiles distribution of TN (g $kg^{-1}$) content of soil in seed farm (*SF*) and non-seed farm (*NS*) sites in Java Island, Indonesia (1970-2003). A = original sites; B = closest to original sites.

**Table 4.** The effects of land management on the changes of some chemical properties of 'sawah' soil in 0 – 20 cm and 0 – 100 cm soil layers in seed farm and non-seed farm sites during the period of 1970 - 2003 in Java, Indonesia

0 - 20 cm

| Soil properties | Seedfarm | | | | Non-seedfarm | | | |
|---|---|---|---|---|---|---|---|---|
| | *n* | mean±SD 1970 | mean±SD[a] 2003 | Change (%) | *n* | mean±SD 1970 | mean±SD[a] 2003 | Change(%) |
| pH H?O (1:2.5) | 18 | 7.13±0.66 | 5.88±1.02*** | -1.25(-17) | 22 | 6.71±0.81 | 5.81±0.81*** | -0.90(-13) |
| Exch. Acidity (kmolc ha$^{-1}$) | 18 | 8.68±3.40 | 12.80±4.60*** | 4.11(47) | 22 | 9.84±2.78 | 13.60±2.90*** | 3.26(38) |
| Exch. Ca (kmolc ha$^{-1}$) | 18 | 60.10±52.20 | 64.20±61.60$^{ns}$ | 4.15(7) | 22 | 61.90±49.50 | 66.80±64.20$^{ns}$ | 4.92(8) |
| Exch. Mg (kmolc ha$^{-1}$) | 18 | 18.80±10.80 | 19.30±11.70$^{ns}$ | 0.49(3) | 22 | 13.20±9.20 | 14.70±9.30* | 1.58(12) |
| Exch. K (kmolc ha$^{-1}$) | 18 | 1.62±0.84 | 1.75±1.13$^{ns}$ | 0.14(8) | 22 | 1.27±0.56 | 0.98±0.67* | -0.30(-23) |
| Exch. Na (kmolc ha$^{-1}$) | 18 | 3.49±2.63 | 2.07±2.88* | -1.42(-41) | 22 | 3.11±2.91 | 1.34±0.96*** | -1.77(-57) |
| ECEC (kmolc ha$^{-1}$) | 18 | 92.70±56.40 | 100.20±66.80$^{ns}$ | 7.47(8) | 22 | 89.30±57.10 | 97.50±67.50$^{ns}$ | 8.19(9) |
| Available P (kg $P_2O_5$ ha$^{-1}$) | 18 | 198±211 | 393±382*** | 194(98) | 22 | 86±49 | 143±105** | 57(67) |

0 - 100 cm

| Soil properties | Seedfarm | | | | Non-seedfarm | | | |
|---|---|---|---|---|---|---|---|---|
| | *n* | mean±SD 1970 | mean±SD[a] 2003 | Change (%) | *n* | mean±SD 1970 | mean±SD[a] 2003 | Change(%) |
| pH H?O (1:2.5) | 18 | 7.26±0.46 | 6.38±0.64*** | -0.89(-12) | 22 | 7.01±0.70 | 6.28±0.72*** | -0.72(-10) |
| Exch. Acidity (kmolc ha$^{-1}$) | 18 | 29.70±12.00 | 41.40±16.00*** | 11.67(39) | 22 | 35.10±17.90 | 43.80±13.40** | 8.75(25) |
| Exch. Ca (kmolc ha$^{-1}$) | 18 | 267.1±179.1 | 278.5±196.7$^{ns}$ | 11.45(4) | 22 | 303.8±268.5 | 261.0±224.4* | -42.8(-14) |
| Exch. Mg (kmolc ha$^{-1}$) | 18 | 98.70±58.60 | 99.60±53.10$^{ns}$ | 0.85(1) | 22 | 62.70±40.70 | 60.00±40.20$^{ns}$ | -2.66(-4) |
| Exch. K (kmolc ha$^{-1}$) | 18 | 7.94±3.20 | 7.14±4.74$^{ns}$ | -0.80(-10) | 22 | 6.01±2.13 | 4.05±2.56*** | -1.96(-33) |
| Exch. Na (kmolc ha$^{-1}$) | 18 | 15.50±4.90 | 10.60±12.20* | -4.88(-31) | 22 | 13.20±7.80 | 6.98±5.09*** | -6.24(-47) |
| ECEC (kmolc ha$^{-1}$) | 18 | 419.0±196.6 | 437.3±216.5$^{ns}$ | 18.28(4) | 22 | 420.8±299.9 | 375.9±243.0$^{ns}$ | -44.9(-11) |
| Available P (kg $P_2O_5$ ha$^{-1}$) | 18 | 654±690 | 1198±1148*** | 544(83) | 22 | 301±255 | 436±379* | 135(45) |

[a] Paired samples T-test [b] Independent-samples T-test between changes of the mean values from 1970 to 2003 of seedfarms and non-seedfarms

Significant level: * = 0.05 < ** = 0.01 < *** = 0.001; ns = not significant

As an essential macro nutrient, K had been added to the soil as potassium chloride (KCl) fertilizer in seed farms, but not in non-seed farms (Lansing *et al.*, 2001). The chemical fertilizer used in non-seed farms sites mostly depended on the farmer's budget condition, and among the three kinds of chemical fertilizers (Urea, Super-phosphate and KCl), KCl was less frequently used by farmers (personal communication).The removal of K through harvest or leaching without enough replacement might have contributed to the decrease of exchangeable K in non-seed farms where the application of K fertilizers was not as much as in seed farms.

Available P content (Table 4) in seed farms significantly increased from 198.5 ± 211.1 to 393.0 ± 382.3 kg $P_2O_5$ $ha^{-1}$ (98%) and from 653.6 ± 690.5 to 1198.2 ± 1147.9 kg $P_2O_5$ $ha^{-1}$ (83%) from 1970 to 2003 in 0–20 cm and 0–100 cm soils layers respectively, while in non-seed farms it increased from 86.0 ± 49.3 to 143.5 ± 105.6 kg $P_2O_5$ $ha^{-1}$ (67%) and from 301.3 ± 254.8 to 436.3 ± 378.6 kg $P_2O_5$ $ha^{-1}$ (45%) in respective soil layers. The rate of increase was higher in seed farms as compared to non-seed farms (Table 4). The results were obviously influenced by differences in land management practice such as fertilizer application, between seed farms and non-seed farms. Seed farms, which were planted with rice and P fertilizer applied following the government recommendation after the GR technology started, accumulated more available P than did in non-seed farms, where the application of P fertilizer was not as much. The excess of available P in Java 'sawah' soils, especially in seed farm, seemed to create an environmental problem. Water flow through run-off and drainage brought dissolved P into water bodies downstream. During the field research in this study, evidence of the water pollution was observed as aquatic plant grew and covered the water surface on the drainage canals in lowland areas. According to Brady and Weil (2002), runoff, leaching and erosion from agricultural land will move some phosphorus into the streams, lakes, ponds and reservoirs, triggering the process of eutrophication. Lansing *et al.*, (2001) found the concentration of P in the streams increasing gradually from upper to lower areas in Bali. Those results were also in agreement with Zhang *et al.*, (2003) who reported that P losses from 'sawah' is one of the potential factors relating to water eutrophication because P content in runoff and leachate were detachable, even when 'sawah' received low doses of P fertilizer.

*Effects of rice cultivation intensity on available silica decrease*

The effects of rice cultivation intensity between seed farms and non-seed farms on the decreasing rate of available Si during the period 1970 to 2003 in Java 'sawah' soils presented in Table 5. Available Si in seed farms decreased with higher statistical level ($p < 0.01$) than in non-seed farms ($p < 0.05$). It is clear that seed farms sites lost more available Si than non-seed farms. In the 0–20 cm soil layer, average content of available Si in seed farms decreased from 1646 ± 581 kg $SiO_2$ $ha^{-1}$ to 1283 ± 533 kg $SiO_2$ $ha^{-1}$ (-22%) while in non-seed farms it decreased from 1440 ± 645 kg $SiO_2$ $ha^{-1}$ to 1202 ± 563 kg $SiO_2$ $ha^{-1}$ (-17%). In the 0-100 cm soil layer the average available Si in seed farms decreased from 7853 ± 4187 kg $SiO_2$ $ha^{-1}$ to 6906 ± 4024 kg $SiO_2$ $ha^{-1}$ (-14%) while in non-seed farms decreased from 5710 ± 2700 kg $SiO_2$ $ha^{-1}$ to 5063 ± 2528 kg $SiO_2$ $ha^{-1}$ (-12%) as shown in Table 5.

Although, the available Si content in Java 'sawah' soils is the highest among the Southeast Asian countries (Kawaguchi and Kyuma, 1977), intensive rice cultivation has been mining Si and exporting it through harvesting processes. Due to this transport of Si out of the field, seed farms where rice is cultivated with higher intensity showed higher decreased rate of available Si than non-seed farms (Table 3). Ma and Takahashi (2002) stated that rice husk accounts for about 20% of the weight of rice grain and up to 20% consists of $SiO_2$. Assuming rice productivity in seed farms and non-seed farms was similar (about 5.5 Mg husked rice per hectare per cropping season), seed farms sites where rice is planted three times a year lost silica in $SiO_2$ form about 660 kg $ha^{-1}$ every year. This is much higher than in non-seed farms. Within the study period, seed farms and non-seed farms had exported 21780 kg $SiO_2$ and 14520 kg $SiO_2$, respectively out of 'sawah' through harvesting processes. These values were much higher as compared with the decreasing rate of available Si in soils. Table 3 shows that available Si content in the 0–20 cm soil layer decreased by 363 kg $SiO_2$ $ha^{-1}$ and 238 kg $SiO_2$ $ha^{-1}$ in seed farms and non-seed farms, respectively. The contribution of other natural silica resources such as irrigation water seemed to play important roles in maintaining available Si content in the soil. Kawaguchi and Kyuma (1977) found that the average Si content in river water (which are the dominant sources for irrigation) in Java was 29.82 mg $SiO_2L^{-1}$. Although average Si content measured in irrigation water was much lower than in river water (14.00 mg $SiO_2L^{-1}$), Si input from this resource could possibly decrease the rate of available Si in 'sawah' soil (Table 4).

## Conclusion

The application of the GR technology from 1970 to 2003 has changed some soil properties of 'sawah' soil in Java, Indonesia. TC and TN contents in 'sawah' soils increased both on seed farms and non-seed farms. Non-seed farms which were planted with rice and upland crops in rotation accumulated higher TC and TN than

Table 5. The effects of cultivation intensity between seed farm and non-seed farm on the changes rate of available silica (kg $SiO_2$ $ha^{-1}$) during the period of 1970-2003 in Java 'sawah' soil, Indonesia.

| | Seedfarm | | | | Non-seedfarm | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 - 20 cm | | 0 - 100 cm | | 0 - 20 cm | | 0 - 100 cm | |
| | 1970 | 2003 | 1970 | 2003 | 1970 | 2003 | 1970 | 2003 |
| *n* | 18 | 18 | 18 | 18 | 22 | 22 | 22 | 22 |
| Mean± SD | 1646± 581 | 1283± 533 | 7853± 4187 | 6906± 4024 | 1440± 645 | 1202± 563 | 5710± 2700 | 5063± 2528 |
| Change mean | | -363 | | -947 | | -238 | | -647 |
| % change | | -22 | | -14 | | -17 | | -12 |
| *T-test* | | ** | | * | | * | | * |

Significant level: * ≤0.05; ** ≤0.01

seed farm sites where rice was planted in a monoculture system over the whole study period. Application of chemical fertilizer without any consideration of the natural supply from the soils or (irrigation) water resulted in a considerable variation in the changes of soils properties among the sites within the study period in both seed farms and non-seed farms site. This study also shows how decreasing rate of available Si is affected by cultivation intensity of rice and topographical position. Seed farms site planted with rice at higher intensity lost more Si than non-seed farms. Within similar land management practices and cultivation intensity, sampling sites located in upland positions decreased in available Si higher than those in lowlands. The adverse effect of the GR in Indonesia is mainly due to improper land management over long period of time.

**Acknowledgements**

The authors would like to express their deep gratitude to Ministry of Education, Science, Sport and Culture of Japan for the financial assistance for this study. The deepest appreciation goes to Dr. Fahmuddin Agus, of the Center of Soil and Agro-climate Research and Development (CSARD) Bogor, Indonesia for providing the necessary support during soil sampling in Java in 2003.

**References**

Ali MM, Saheed SM, Kubota D, Masunaga T and Wakatsuki T 1997: Soil degradation during the period 1967-1995 in Bangladesh. I. Carbon and nitrogen. *Soil Sci. Plant Nutr.*, **43**, 863-878.

Al-Kaisi MM, Xinhua Y and Licht AM 2005: Soil carbon and nitrogen changes as influenced by tillage and cropping systems in some Iowa soils. *Agriculture, Ecosystems & Environment*, **105**, 635 – 647.

FAO 1984: Land, Food and People. FAO Economic and Social Development Series, 30. Rome: Food and Agriculture Organization of the United Nations.

Guo LP and Lin ED 2001: Carbon sinks in cropland soils and the emission of greenhouse gases from paddy soils: a review of work in China. *Chemosphere, Glob. Chang. Sci.*, **3**, 413-418.

Indonesia Ministry of Agriculture 1995: Total 'sawah' and harvested area in 1994. (Total luas 'sawah' dan luas panen tahun 1994). Jakarta (in Indonesian).

Indonesian Ministry of Agriculture 2001. The rice production in Indonesia (Produksi padi di Indonesia), Jakarta (in Indonesian).

IRRI 1986: Annual Report for 1985. International Rice Research Institute, Los Banos, Philippines.

Japan Soil Science and Plant Nutrition 1986: Available nitrogen. *In* Standard Method of Soil

Analyses (Dojou Hyojun Bunseki-sokutei Hou). Ed. Yutaka Onikura. pp. 118 – 121, Hakuyusha, Tokyo (in Japanese).

Kawaguchi K and Kyuma K 1977: Paddy soil in tropical Asia. Their material, nature and fertility. The Univ. Press of Hawaii, Honolulu, pp. 258.

Kirby JM and Voase AJR 2000: Drying of some Philippine and Indonesia puddle rice soils following surface drainage: Numerical analysis using swelling soil flow model. *Soil and Tillage Research*, **57**, 13-30.

Kundu DK and Ladha JK 1995: Efficient management of soil and biologically-fixed $N_2$ in intensively cultivated rice field. *Soil Biol. Biochem.*, **27**, 431-439.

Lansing JS, Kremer JN, Gerhart V, Kremer P, Arthawiguna A, Sutara SKP, Suprapto, Suryawan IB, Arsana IG., Scarborough VC, Schoenfelder J and Mikita K 2001: Volcanic fertilization of Balinese rice paddies. *Ecol. Econ.*, **38**, 383-390.

Nair PKR 1985: Classification of Agroforestry Systems. *Agrofor. Syst.*, **3**, 97-128.

Nelson DW and Sommers LE 1982: Total carbon, organic carbon and organic matter. *In* Methods of soil analyses, No. 9, Part 2, Ed. Page AL, DE Baker, Ellis R Jr, Keeney DR, Miller RH and Rhoades JD. Am.Soc. of Agron. Inc., Soil Sci. Am., Inc. Publisher, Madison, Wisconsin, p: 552-553.

Otsuka K 2000: Role of agricultural research in poverty reduction: lesson from the Asian experience. *Food Policy*, **25**, 447-462.

Pimentel D 1996: Green Revolution and Chemical Hazards. *The Sci. of the Tot. Environ. 188 Suppl.*, **1**, 86-98.

Rahman S 2003: Environmental impact of modern agricultural technology diffusion in Bangladesh: an analysis of farmers' perceptions and their determinants. *Journal of Environmental Management*, **68**, 183-191.

Redclift M 1989: The environmental consequences of Latin America's agricultural development: some thoughts on the Brundtland Commission report. *World Development*, **17**, 365-377.

Roger PA and Ladha JK 1992: Biological $N_2$ fixation in wetland rice fields: estimation and contribution to nitrogen balance. *Plant Soil*, **141**, 41-45.

Singh RB 2000: Environmental consequences of agricultural development: a case study from the Green Revolution state of Haryana, India. *Agriculture, Ecosystem and Environment*, **82**, 97-103.

Tiessen H, Cuevas E and Chacon P 1994: The role of soil organic matter in sustaining soil fertility. *Nature*, **371**, 783-785.

Tomar SS, Tembe GP, Sharma SK and Tomar VS 1996: Studies on some land management practices for increasing agricultural production in Vertisols of Central India. *Agricultural Water Management*, **30**, 91-106.

Verburg PH, Veldkamp TA and Bouma J 1999: Land use change under condition of high population pressure: the case of Java. *Global Environmental Change*, **9**, 303-312.

Wakatsuki T, Shinmura Y, Otoo E and Olaniyan GO 1998: African-based sawah system for the Integrated Watershed Management of the Small inland Valleys of West Africa. FAO, Water Report, No. 17, 56-79.

Zhang HC, Cao ZH, Shen QR and Wong MH 2003: Effect of phosphate fertilizer application on phosphorus (P) losses from paddy soils in Taihu Lake Region: I. Effect of phosphate fertilizer rate on P losses from paddy soil. *Chemosphere*, **50**, 695-701.

Zhang M and He Z 2004: Long-term changes in organic carbon and nutrients of an Ultisol under rice cropping in southeast China. *Geoderma*, **118**, 167-169.

# "Sawah" Eco-technology: Farmers' Personal Irrigated "*Sawah*" Systems to Realize the Green Revolution and Africa's Rice Potential.

T. Wakatsuki[1], M.M. Buri[2], R. Bam[3], S.Y. Ademiluyi[4], and I.I. Azogu[4]

[1]*School of Agriculture, Kinki University, Nara 631-8505, Japan;* [2]*CSIR-Soil Research Institute, Kumasi, Ghana;* [3]*CSIR-Crops Research Institute, Kumasi, Ghana;* [4]*National Centre for Agricultural Mechanization, Ilorin, Nigeria*

**Abstract**

Among the 250 million ha of lowlands in Sub Sahara Africa (SSA), only about 10% are estimated as appropriate sites for sustainable irrigated *sawah* system development because of hydrological, topographical, and pedological limitations. Of all lowland types, inland valleys are the priority because of relatively easy water control. However, it has also became clear that some huge flood plains in Guinea savannah zone can also be given priority if appropriate cropping calenders can be selected. Both large-scale and small-scale irrigation projects, typically Official Development Assistance (ODA) assisted, have been very costly because of major dependency on heavy engineering works by outside expertise. Due to their high construction costs, economic returns remain negligible or negative for long periods (20-30 years), project ownership remains with the government (engineers) rather than with the farmers and therefore neither the development nor management is sustainable. Site specific farmers' personal irrigated *sawah* system development (sawah eco-technology) offers low cost irrigation and water control for rice intensification, with sustainable paddy yield of 4-6 t $ha^{-1}$. If improved agronomic practices are applied, such as System of Rice Intensification (SRI), based on the *sawah* systems, paddy yield can be higher than 10t $ha^{-1}$. African lowlands are quite diverse and variable and therefore careful site-specific *sawah* development and management technologies have to be researched, developed and disseminated. To develop and manage *sawah* systems by local farmers, self-propelled efforts and small-scale equipment such as hydro-power tillers are needed. After many trial and error processes (1997-2011), the *sawah* eco-technology has been successfully tested in Ghana and Nigeria, especially in locations where appropriate sites were selected and local leading farmers trained and supported by proper backstopping. This paper discusses the main targets to realize sustainable dissemination of sawah eco-technology which are composed of four important skills and technologies: (i) site selection and site specific *sawah* system design, (ii) skills for efficient and cost effective *sawah* systems development using hydro-power tiller, (iii) rice farmers' empowerment for successful development and management of sawah systems, and (iv) sawah-based rice farming to realize at least sustainable paddy yields > 4t $ha^{-1}$ and 20 ton annual paddy production per one set of power tiller for at least three years after the initiation of new sawah development. Establishment of institutional training and dissemination systems for *sawah* eco-technology and basic research to get sustainable paddy yields > 10t $ha^{-1}$ are also important. Since rice farmers have to master relatively wider range of skills including ecological engineering,

intensive on-the-job training is very important and necessary. Once mastered, however, the skills can be transferred from farmer-to-farmer for scaling out activities and faster adoption. Examples of successes which require scaling out are Ashanti in Ghana and Bida, Kebbi, Abakaliki, Akure, Zaria and Adani in Nigeria.

## Introduction

As described in earlier publications (Wakatsuki, et al, 1998; 2011; Hirose and Wakatsuki, 2002; Wakatsuki and Masunaga 2005), the sawah eco-technology is the missing technology to improve soil and water management as well as the income generation base of rural society in sub-Saharan Africa (SSA). Among the 250 million ha of lowlands in SSA (Windmeijer and Andriesse, 1993), only about 10% (20 million ha) are estimated to be appropriate sites for sustainable irrigated *sawah* system development, of which 9-20 million ha are in small inland valleys, 8-15 million ha in floodplains, 4-9 million ha in coastal deltas, and 1-5 million ha in inland basins as shown in Table 1 (Wakatsuki et al. 1998, Abe and Wakatsuki 2011).

**Table 1.** Distribution of lowlands and potential irrigable 'sawah' area in SSA

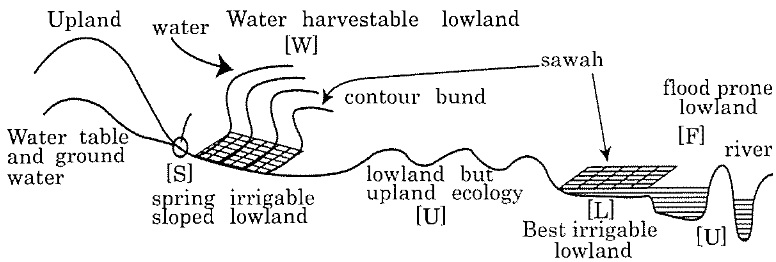
| Classification | Area (million ha) | Area for potential 'sawah' development (million ha) | |
|---|---|---|---|
| Coastal swamps | 17 | 4-9 | 25-50% |
| Inland basins | 108 | 1-5 | 1-5% |
| Flood plains | 30 | 8-15 | 25-50% |
| Inland valleys | 85 | 9-20 | 10-25% |

Source: Andreisse & Windmeijer, 1993, Wakatsuki, 2002

*Note:*

***Even though the priority area is inland valleys, some flood plains can be highly suitable such as in the Sokoto and Kebbi states of Nigeria.***

As shown in Figure 1, appropriateness is affected by hydrological, topographical, and pedological considerations (Hirose and Wakatsuki 2002). Of all the lowland types, inland valleys are the priority for the application of the sawah eco-technlogy because controlling water in them is relatively easy. However, during the 2011 growing season (April-September), it has now become clear that some huge flood plains within Guinea savannah zone, such as Sokoto or Kebbi states in Nigeria can also be given high priority if appropriate cropping calenders can be selected. Both large-scale and small-scale irrigation projects, typically created under Official Development Assistance (ODA), have been very costly (FAO, 1998; Wakatsuki et al., 2001; JICA, 2008; MOFA and AfDB, 2008) because of dependence on heavy engineering works and outside expertise (Table 2). Due to high construction cost, economic returns remain negligible or negative for long periods (20-30 years). Project ownership remains with the government (engineers) rather than with the farmers, because farmers cannot develop the systems by themselves. Therefore, neither the development nor management is sustainable.




Irrigation options : Sawah to sawah / contour bund water harvesting, spring, seepage, river by dam and dyke, peripheral canal, interceptor canal, tank, pump

Lowland sawah development priority
[S] > [L] > [F] > [W] > [U]

**Figure 1.** Diversity in topography and hydrology of inland valley in Sub-Saharan Africa. Topography and hydrology are also changed in various agro-ecological zones. Pedological characteristics are changed depending on geology, climate, topography, and vegetation

The *sawah* eco-technology offers low-cost irrigation and water control for rice intensification with sustainable paddy yield of more than 4t $ha^{-1}$ within sufficiently large area of 5-10 ha using one power tiller per farmer or farmers' group. Although the sawah team at Kebbi state Fadama III and ADP, Nigeria, got more than 7t $ha^{-1}$ in 2011 using standard sawah technology. If improved agronomic practices, such as the System of Rice Intensification (SRI) or others with the *sawah* systems are applied, paddy yield can reach more than 10t $ha^{-1}$ (Tsujimoto et al. 2009).

However, African lowlands are quite diverse and different from Asian lowlands as shown in Figure 1. Therefore careful site-specific *sawah* development and management technologies must be researched, developed, and disseminated through intensive On-The-Job training (OJT). The development and management of *sawah* systems requires that local farmers be self-motivated and have access to small-scale equipment, such as hydro-power tillers. After many trial-and-error processes (1997-2011) and the addition of numerous innovation processes, the *sawah* system has since been successfully tested in Ghana and Nigeria, especially in locations where appropriate sites were selected, local leading farmers trained and proper backstopping mechanisms provided by scientists (Hirose and Wakatsuki 2002; Wakatsuki et al. 2001; Wakatsuki and Masunaga 2005; Oladele et al. 2010; Abe and Wakatsuki 2011).

**Table 2.** Comparison of farmers' sitespecific personal irrigated *sawah* system development with large - and small-scale ODA-based developments, and traditional rice cultivation system in inland valleys of Ghana and Nigeria.

| | Large-scale development | Small-scale development | *Sawah* approach | Traditional system |
|---|---|---|---|---|
| Development cost ($/ha) | 20,000–30,000 | 10,000–30,000 | 1,000–3,000 | 30–60 |
| Gross revenue ($/ha)† | 2,000–3,000 | 2,000–3,000 | 2,000–3,000 | 500–1,000 |
| Yield (t/ha) | 4–6 | 4–6 | 4–6 | 1–2 |
| Running cost, including machinery ($/ha)† | 600–800 | 600–800 | 400–600 | 200–300 |
| Farmer participation | Low | Medium–High | High | High |
| Project ownership | Government | Government | Farmer | Farmer |
| Adoption of technology | Long, difficult | Slow, relatively easy | Medium to short, needs intensive demonstration and on-the-job training (OJT) program | Low technology transfer |
| Sustainable and endogenous development based on innovation and adaptive evolution | Low(contractors' heavy machinery used by contractors in development) | Low - medium | High (farmer-based and small power-tiller used in development and management) | Medium |
| Adverse environmental effect | High | Medium | Low | Medium |

† Assuming 1 ton paddy is worth US$ 500; one power-tiller costs $3,000-9,000 in West Africa depending on the brand quality and accessories (2010 values). Selling prices, however, are $1,500 -$4,500 for farmers in Asian countries.

The *sawah* approach involves four important skills and technologies (Table 3): (i) site selection and site-specific *sawah* system design, (ii) skills for cost-effective *sawah* system development using a small hydro-power tiller, (iii) rice farmers' empowerment for successful development and management of sawah systems, and (iv) *sawah*-based rice agronomy, including best variety selection and management to realize at least the sustainable paddy yield of more than 4t $ha^{-1}$. The establishment of institutional training and dissemination systems for *sawah* eco-technology transfer (Buri et al. 2009) is necessary. The co-ordination of farmers' group formation and land-tenure arrangements for secured rent (Oladele 2010) to sustain sawah development are very important and necessary. Training of leading *sawah* farmers is key. Leading sawah farmers who are properly trained can train other farmers or farmer-groups (farmer to farmer training) to develop *sawah* and manage *sawah*-based rice farming by themselves. This is the final goal of sawah eco-technology.

In 2011, the sawah eco-technology has reached the stage of making a strong impact for farmers to realize the Green Revolution. If farmers properly grasp the four components of the *sawah* eco-technology, they can develop their personal irrigated sawah systems and realize 20-50 tons of paddy production per season using one power tiller within three years after the initiation of new *sawah* development. The technology can be transferred from farmer to farmer. This means if 500 leading farmers are trained, the technology can spread like wild fire for the realization of the long-awaited Green Revolution in Africa. Obtaining only high yield is not enough. Rice farmers need to cultivate enough area of *sawah* in order to generate enough income.

Specific target is to train more than 500 qualified leading sawah farmers who can develop their personal irrigated sawah systems and realize 20-50 ton of paddy production per season, which is equivalent to $10,000 - $25,000 gross, using one power tiller, which costs $3000-$5000 per set, within three years after the initiation of new sawah development. This will result in new irrigated rice field of 2500 - 5000 ha in inland valleys and other major lowlands. Traditional ODA-based development of such 2,500-5,000ha irrigation systems for rice cultivation cost $50 - $100million only for development without any training for management. In addition the development is done by outside experts and not local experts or farmers. Therefore the system cannot be expanded if ODA stops. "*Sawah*" eco-technology, however, will provide the same scale of development with only $3 - $5million as described below with sustainable development as a result of the on-the-job training of 500 qualified leading *sawah* farmers at the same time. These farmers will be able to develop new *sawah* fields endogenously.

At this stage, large scale action research and dissemination actions both in inland valleys and flood plains are needed in the major agro-ecological zones of all 10 regions in Ghana and at least 20 major states in Nigeria, to make adaptive evolution and endogenous development of prototype Sawah eco-technology for scaling up the past and current successful results achieved during MEXT project (2007-2011) and JIRCAS project (2008-2011) to the whole of Ghana and Nigeria as primary target, as well as Togo and Benin under the SMART-IV Project. Finally the whole of West and Sub Saharan Africa can make a real impact towards the realization of the rice Green Revolution.

**Table 3.** Four important skills for *sawah* eco-technology (approach) required by farmers' to develop and manage site-specific Personal irrigated *sawah* systems and sawah based rice farming (SERIF) through their own efforts.

**(1) Skills for Site Selection and *Sawah* system design**

**(a) Water sources & quality**
(>10 L/s, >5 months/year)
Stream/River, Spring, Seepage, Flood, Rainfed

**(b)Topography and soil**
Ongoing & potential rice area >10ha,
Slope <1 -2%,
surface roughness
Soil texture
Soil fertility

**(c) Socio - economics**
Strong will
Market access
Land tenure
Secured lent

**(d) *Sawah* system design**
Sawah layout and total potential area
Shape & sawah size
Water intake, distribution and control
Spring & sawah to sawah , and diversion canal
Stream/seepage
Simple dyke & diversion canal
Weir and Canal
Fish pond, dam lake
Pump irrigation
Interceptor canal
Contour bund system
Flood control by drainage or dam
Drought control by pond/water -harvest
Soil movement and quality of leveling
Bund layout and quality

> Action research & on -the -job training on site - specific *sawah* development & management
>
> On the job collaboration between farmers & scientists, engineers, and extension office is essentially important
>
> Farmers know site specific hydrological conditions which are the most important for site selection

> The successful example of *Sawah* system development:
> (1) Oasis type pump irrigation in floodplain (Sudan savanna zone, Kebbi state)
> (2) Spring based irrigation system (all climatic zones)
> (3) Overflow dykes on small rivers (Guinea savanna zone, forest transition zone, forest zone)

**(2) Efficient and Low cost Sawah Development: Skill & Technology**

(a) Skills for development
Skill for power -tiller operations
Plowing and Puddling
Soil Moving
Surface leveling & smoothing
Powertiller management

(b) Cost
Power -tiller for development (10ha /power tiller)
Power -tiller spare parts
Fuel for development
Bush clearing, destumping
Bunding and surface treatment
Canal construction
Additional hired labors
Tools and materials
Scientist & engineers cost
Extension officer cost
Farmers' training cost

> **Action research & on -the -job training on site - specific *sawah* development & management**

> ***Sawah* development: at least 10ha per one Power -tiller**

> **Target cost: $1000 - 3000/ha**
>
> **Target speed of development: >3ha/year /powertiller**

**(3) Rice farmers enpowerment**
Group organization
Selection of leader
Support to the group and leader
Training powertillers ' assisted sawah development
Training powertillers assisted sawah based rice farming
Post harvest technology
Marketing and profit equity
Loan condition to acquire powertillers
Support for rental and acquire land for sawah development

**(4) Sawah based rice farming**
Management of water control facilities: water sources, intakes, and distributions
Water equity and canal management
Sawah water control
Leveling, smoothing
Bunding
Puddling skills
Nursery and trans - planting
Weed, pests, and birds management
Carbon sequestration and organic matter management
Fertilization and nutrient management
Variety election
Yield target
Cost effective *sawah* based farming
Mono, two, double,& other cropping
Advanced *sawah* - based farming

> **(1)Immediate target:**
> **Paddy yield >4t/ha, >20ton paddy /powertiller**
>
> **(2)>50t paddy /year /power tiller will accelerate *sawah* development**
>
> **(3) Basic research on sustainable paddy yield >10t/ha is important**

> (1) To train qualified sawah farmers and or groups who could develop sawah >5ha and get annual paddy production >20ton using one powertiller within three years after the initiation of sawah development.
> (2) To train the leading *Sawah* farmers is the key for sustainable and endogenous sawah development. The leading farmers can train farmers and farmers groups to achieve the target as qualified *Sawah farmers* .
> (3) If site selection is suitable for sawah development, sawah is developed more easier in Africa than that in Asia.

> **Minimization of outside funds is key for sustainable and endogenous development : farmers to farmers technology transfer sites > > sites of extension officers > researchers' demonstration sites**

## A general time schedule for establishing a *sawah* eco-technology system model of 2-3 ha

**I. Site selection**: Spend 2-3days per potential area and specifically observe and examine the various land attributes.

(1) Priority areas are the ongoing Fadama and lowland rice cultivation sites: Potential area should be larger than 5-10ha for the sustainable application of sawah eco-technology. The best season for site selection will be from September/October (just before harvesting) to January/February (just after harvest). Intensive interaction with rice farmers on the local hydrological conditions for the past 10-15 years is important.

(2) Secured continuous water flow: > 5months, base water discharge: > 20 l/sec, (i.e., >1500 - 2000 $m^3$/day), potential irrigated *sawah* area: >10-20 ha,

(3) No strong flood attack: Flood depth should be < 50cm and continuation of the flood should not exceed 3-4days, Flood water discharge should be < 10 ton/sec

(4) Flat and very gentle slope are preferable (< 2%). If slope is < 1%, leveling operation would be easy.

(5) Strong will of rice farmers to master *sawah* technology skills and *sawah* development by farmers' self support efforts

(6) Good access road is necessary for demonstrations

**II. New Sawah Development for demonstration: 2-3 months**

Three to four extension officers from state Agricultural Development Project (ADP) or Fadama III offices and 3-10 active farmers which should be trained through intensive OJT by one or two sawah specialists (Sawah specialists of SRI and CRI as well as MOFA extension officers in Ghana, IITA's Hirose Project, NCAM *sawah* team, UNN and Abeokuta *sawah* teams in Nigeria).

(1) Bush clearing, de-stumping, and delineation of possible sawah area: : 10-20 working days/ha

(2) Site survey and mapping: 1-3 working days/ha
Put in 1-3 of about 100 m X and Y axis lines using survey tools, such as laser assisted Total Station (Cannon Co. Ltd.) if possible. If not available, use 90°crossed line using simple measuring tools. Draw upland and lowland borders and river/canal line, land owner/tenure lines.

*Note: Since farmers cannot use such tools, sawah eco-technology uses water as a guidance of topography. Therefore sawah system development must be done using water. Water shows height difference. Skilled sawah staffs can make good canal line slope, not too steep to avoid canal cutting, using water. Sawah plot levelling can be also done using water and soil as a marker within ± 5cm height difference without using such sophisticated laser apparatus.*

*(3)* *Sawah* delineation based on contour line with 30 cm height difference: 5 working days
- (a) Should be started from the lowest valley bottom at each land boundary/tenure lines,
- (b) Should be a straight line and as large as possible for efficient use of power tiller,
- (c) use pegs and rope to delineate bunding location, field borders and canal lines

(4) Bunding: 15-25 working days/ha
The standard size of bund is 50 cm width x 50 cm height (± 20 cm)
- (a) Big bunds for flood prone areas and field boundaries
- (b) Standard bunds for major *sawah* delineation
- (c) Small bunds for sub-*sawah* delineation

(5) Canal and drainage lines: 10-60 working days/ha
Appropriate slope of canal should be less than 1% (preferably 0.1-0.5%).
If canal is too steep, bottom soils will be eroded and would cave in.

(6) Dyke: 30-50 working days/ha. About 500 sand bags (30kg each) reinforced with wooden piles and plank can manage to lift the central river water height by 1-1.5m with 10-15m width of about 5,000-10,000 ha size of watershed under 1500 mm annual rainfall. If watershed size is 2500-5000, about 300 sand bags should be enough. Labour requirements will be 30 mandays.

(7) Nursery preparation: 3 working days/ha in three phases at three week intervals, one day for each phase. Nursery should be prepared 15 to 25 days before transplanting

*(8)* *Sawah* ploughing, puddling, leveling and smoothening: 50-80 working days/ha

**III. Sawah based rice farming in the first year of new sawah development**

*(1)* *Sawah* water control: 10-40 working days/ha

*(2)* *Sawah* systems maintenance: 10-30 working days/ha

(3) Transplanting: 10-20 working days/ha
(4) Fertilization: 2-3 working days/ha
(5) Weeding:6-7 working days/ha
(6) Bird-scaring:10-30 working days/ha
(7) Harvest: 7-15 working days/ha
(8) Threshing:10 working days/ha

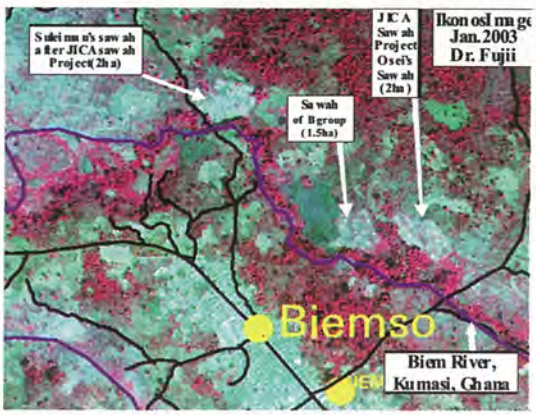
## IV. Overall Target for sustainable sawah development and sawah eco-technology dissemination

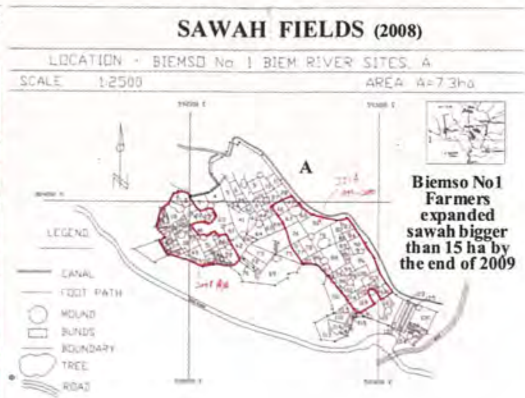
The final goal is to realize 20-50 tons of paddy production at a total revenue of US $10,000-25,000 per year using one power tiller (cost is $3,000-$5,000) within three years after the initiation of new sawah development. If paddy yield is 4t $ha^{-1}$ and only mono cropping is possible, at least 5ha of sawah can be developed using one power tiller.

The most important factor in site selection, appropriate *sawah* system design, development and management is collaboration between researchers and farmers. Scientists and extension officers should have the skills for *sawah* development. Although local farmers do not know *sawah* technologies (before the project starts), they are very familiar with the site-specific hydrological conditions that scientists and extension officers need to know for *sawah* development. Thus, collaborative action-research between farmers and scientists is essential. The priority for site selection is the inland valleys and to some extent the flood plains depending on location and existing conditions. The water conditions of inland valley streams are critical. Water has to flow for more than 5 months continuously, with a discharge of more than 10 l $s^{-1}$. Otherwise, farmers have to develop additional ponds/wells/dug-out to secure water for sustainable *sawah*-based rice cultivation. If floods reach deeper than 50 cm and continue for over 1 week with a discharge of more than 10 $m^3$ $s^{-1}$, major flood control measures have to be put in place. This is difficult for farmers' groups at the first stage of *sawah* development. Therefore, inland valleys that will require such extra inputs should be avoided in the demonstration and training stages.

Some examples of following photographs on next pages show autonomous expansion of Sawah system in inland valley ecosystems at Bida and Zaria, UN-vilalge, Nigeria and Adugyama, Biemso No1, Baniekrom, and Sokwae in Ashanti, Ghana






## Cost effectiveness of *sawah* approach

Cost-effective *sawah* development is critical (Table 4). Although the cost of applying the *sawah* approach is less than 10% that of the cost of ODA-based irrigation schemes (Table 1), the initial *sawah* development relies heavily on use of a power-tiller, which makes up 50% of the development cost. Therefore, apart from the importance of training power-tiller operators (Ademiluyi, 2010), high-quality, durable, and low-cost power-tillers are necessary (Kolawole et al. 2011). Once *sawah* is developed, power- tiller cost for rice farming will not be a major problem. If farmers are well trained during the first year (normally difficult period of *sawah* development), *sawah*-based rice farming would be more sustainable than old-style ODA- based irrigation projects. Since the *sawah* approach gives sustainable low-cost personal irrigated *sawah* system development, which costs about 10% of ODA-based irrigated *sawah* development, there may be the need for special subsidization to encourage *sawah* development by farmers in the first year.

Asian farmers can buy similar power-tillers for just $1500-4500, while commercial prices of power-tillers in Ghana and Nigeria are $3000-9000. So it may be necessary to apply a special subsidy to encourage farmers to develop *sawah* in the first year. If sawah developments are accelerated and power tiller markets are expanded in the near future, power tiller cost would be in the same price ranges as in Asia ($2000-$5000 including shipping cost). Fortunately, African lowlands especially inland valleys have quite adaptable topography and wide areas of virgin land to develop *sawah* systems rapidly. Once African farmers able to acquire the necessary skills and *sawah* systems developed, *sawah*-based rice farming will be more sustainable than the old-style ODA-based irrigation projects.

**Table 4a.** Cost and Income (US $) of Site Specific Personal Irrigated *Sawah* Development and *Sawah*-based rice cultivation (Ghana & Nigeria, 2009)

| Activity | Cost/income elements, performance/durability of pump & power tillers | Spring-based (mean slope 1.5%) | Flood plain (mean slope 0.5%) | Stream dyke-based (mean slope 1%) | Pond-based (mean slope 1%) | Pump-based** (mean slope 1%) | Non *sawah* (2%) |
|---|---|---|---|---|---|---|---|
| **A. *Sawah* development activities (first year of new *sawah* development only, per ha)** | | | | | | | |
| Clearing & destumping | 10-20 working days‡ | 70 | 70 | 70 | 70 | 70 | 35 |
| Bunding | 20-30 working days‡ | 100 | 70 | 85 | 85 | 85 | NA |
| Ploughing | 20-30 working days‡ | 100 | 70 | 85 | 85 | 85 | NA |
| Puddling, soil movement, leveling | 30-50 working days‡ | 200 | 135 | 170 | 170 | 170 | NA |
| Pumping machine cost | 3 ha/year† | NA | 50 | Na | 30 | 200 | NA |
| Power tiller cost# | 2-3ha/yr, 6-15ha/life | 700 | 500 | 600 | 600 | 600 | NA |
| Main canal | $1000 for 100m/ha | NA | Na | 100 | 100 | Na | NA |
| Branch canal | $35 for 100m/ha | 70 | 35 | 70 | 70 | 70 | NA |
| Interceptor canal | $35 for 100m/ha | 35 | Na | 35 | 35 | 35 | NA |
| Dyke/weir | $400 for 20m x 5m x 3m per 3ha/3 | NA | Na | 150 | Na | Na | NA |
| Pump fuel | 3-20 days ($20/day) | NA | 100 | Na | 60 | 400 | NA |
| Flood control | $700 for 150m x 2m x 2m per 3ha/3 | NA | 270 | 70 | Na | Na | NA |
| Pond construction | $1400 for 20m x 20m x 2m per 3ha/3 | NA | Na | Na | 500 | Na | NA |
| Total cost of development | | 1275 | 1300 | 1435 | 1805 | 1715 | 35 |

‡1 working day cost $3.5. †Pumping machine: 15% depreciation, 10% spare parts. #Power tiller cost: $5000 for 3-5 years life, 15% depreciation, 10-20% spare parts; initial *sawah* development claims heavy load on power tiller, which comprises 50% of cost of development. *Direct sowing and/or dibbling. **Pump based systems have poor economic returns, if yield is same as other systems.

Since rice farmers have to master a wide range of skills, including ecological engineering, intensive on-the-job training continuing for 5-6 months is very important. One of the factors working against realization of green revolution in Africa is the failure to scale up successful results of past agricultural research (Ejeta, 2010). We do not want this to be the lot of this promising technology. The *sawah* approach has therefore arrived at a scaling-up stage to show clear road map for rice green revolution in Africa (Table 5). Thus our *sawah* approach becomes comparable for research, development, and dissemination of good varieties.

**Table 4b & c:** Cost and Income (US $) of Site Specific Personal Irrigated *Sawah* Development and *Sawah*-based Rice cultivation (Ghana & Nigeria, 2009)

| Acticvity | Cost/income elements, performance/durability of pump & power tillers | Spring-based (mean slope 1.5%) | Flood plain (mean slope 0.5%) | Stream dyke-based (mean slope 1%) | Pond-based (mean slope 1%) | Pump-based** (mean slope 1%) | Non sawah (2%) |
|---|---|---|---|---|---|---|---|
| **B. Sawah-based rice farming cost (first year only, per ha)** | | | | | | | |
| Nursery bed | 1-2 work- days‡ | 5 | 5 | 5 | 5 | 5 | 15 |
| Seed cost | 30-90kg ($10 per 10kg) | 30 | 30 | 30 | 30 | 30 | 90 |
| Sawah water mag,t | 12-35 work- days‡ | 40 | 40 | 40 | 40 | 120 | NA |
| Transplanting | 15 work-days ($3/day) | 45 | 45 | 45 | 45 | 45 | NA |
| Rope & markers | 5 bundles ($2/bundle) | 10 | 10 | 10 | 10 | 10 | NA |
| Weeding labour | 6-7 work-days ($3/day) | 20 | 20 | 20 | 20 | 20 | 50 |
| Herbicide | 5Litres ($8/L) | 20 | 20 | 20 | 20 | 20 | NA |
| Fertilizer | 200kg/4bags($20/50kg) | 80 | 80 | 80 | 80 | 80 | NA |
| Fertilizing | 3-4 work-days ($3/day) | 10 | 10 | 10 | 10 | 10 | NA |
| Bird scaring | 10-30 work-days ($1.5/day) | 20 | 20 | 20 | 20 | 20 | 40 |
| Harvesting | 7-15 work-days ($4/day) | 60 | 60 | 60 | 60 | 60 | 30 |
| Threshing | 10 work-days‡ | 35 | 35 | 35 | 35 | 35 | 15 |
| Sawah-based rice farming cost | | 375 | 375 | 375 | 375 | 465 | 240 |
| Total cost in first year | | 1650 | 1765 | 1810 | 2180 | 2180 | 275 |
| Yield | 4 -4.5 t ha$^{-1}$ | 4.5 | 4.0 | 4.5 | 4.5 | 4.0** | 1.5 |
| Gross income | $500/t paddy | 2250 | 2000 | 2250 | 2250 | 2000 | 750 |
| Net income | | 600 | 325 | 440 | 70 | 180 | 475 |
| **C. Sawah-based rice farming cost (subsequent year, per ha)** | | | | | | | |
| Pump | 2-10 days($15/day) | NA | 50 | NA | 30 | 150 | NA |
| Ploughing | 5-7 work-days‡ | 15 | 15 | 15 | 15 | 15 | NA |
| Puddling, leveling | 6-9 work-days‡ | 30 | 20 | 30 | 30 | 30 | NA |
| Power tiller | 10 ha/year, life 5-7 yrs | 90 | 80 | 90 | 90 | 90 | NA |
| Maintenance of canal, dyke, pond | 15% of new construction | 15 | 70 | 70 | 90 | 15 | NA |
| Nursery bed | 1-2 work- days‡ | 5 | 5 | 5 | 5 | 5 | 15 |
| Seed cost | 30-90kg ($10 per 10kg) | 30 | 30 | 30 | 30 | 30 | 90 |
| Water mag't | 20 work- days ($2/day) | 40 | 40 | 40 | 40 | 40 | NA |
| Transplanting | 15 work-days ($3/day) | 45 | 45 | 45 | 45 | 45 | NA |
| Rope tec | 5 bundles ($2/bundle) | 10 | 10 | 10 | 10 | 10 | NA |

| Acticvity | Cost/income elements, performance/durability of pump & power tillers | Spring-based (mean slope 1.5%) | Flood plain (mean slope 0.5%) | Stream dyke-based (mean slope 1%) | Pond-based (mean slope 1%) | Pump-based** (mean slope 1%) | Non sawah (2%) |
|---|---|---|---|---|---|---|---|
| Weeding labour | 7 work-days ($3/day) | 20 | 20 | 20 | 20 | 20 | 50 |
| Herbicide | 5Litres ($8/L) | 20 | 20 | 20 | 20 | 20 | NA |
| Fertilizer | 200kg/4 bags ($20/50kg) | 80 | 80 | 80 | 80 | 80 | NA |
| Fertilizing | 3work-days ($3/day) | 10 | 10 | 10 | 10 | 10 | NA |
| Bird scaring | 15-30 work-days ($1.5/day) | 20 | 20 | 20 | 20 | 20 | 40 |
| Harvesting | 15 work-days ($4/day) | 60 | 60 | 60 | 60 | 60 | 30 |
| Threshing | 10 work-days‡ | 35 | 35 | 35 | 35 | 35 | 15 |
| Sawah-based rice farming cost Total cost in first year | | 525 | 610 | 580 | 630 | 675 | 240 |
| Yield | 4-4.5t $ha^{-1}$ | 4.5 | 4.0 | 4.5 | 4.5 | 4.0** | 1.5 |
| Gross income | $500/t paddy | 2250 | 2000 | 2250 | 2250 | 2000 | 750 |
| Net income | | 1725 | 1390 | 1670 | 1620 | 1325 | 510 |

**Table 5.** Roadmap to African Rice Green Revolution by Sawah Eco-technology

| Period | Activity |
|---|---|
| 1986-2002 | 10 sites. 6ha of *Sawah*, 17years of trial and error. JICA/CSIR and MEXT assisted sawah project. West African wide survey on traditional rice farming and basic research on site specific sawah development by farmers' self support efforts at Bida, Nigeria and Kumasi, Ghana |
| 2003-2007 | 20 sites, 30ha, Benchmark watershed. MEXT assisted basic research sites. Basic action research to develop site specific personal irr igated *Sawah* by farmers at Bida in Nigeria and Kumasi area in Ghana |
| 2007-2011 | >100 sites, >200ha, *Sawah* eco-technology. MEXT specially assisted promoted research. Kinki Univ./NCAM/Fadama III/SRI/CRI, JIRCAS, SMART -IV. *Sawah* eco-technology establishment and to prepare large scale action research on *Sawah* eco-technology dissemination in Nigeria, Ghana, Togo and Benin |
| 2012-2016 | >500 sites, >2500ha of *Sawah* in each country. African adaptive *Sawah* eco-technology dissemination, evolution and endogeneous development. Kinki Univ./NCAM/Fadama III/SRI/CRI, JIRCAS, SMART -IV and JICA-CARD. To start large scale action research on *Sawah* eco-technology in the whole of Ghana, Nigeria as well as Togo, Benin and others in West Africa and Sub-Saharan Africa. |
| 2017-2022 | > 2500 sites, > 25000ha of *Sawah* in each country. African wide adaptation and dessimination and endogeneous *Sawah* eco-technology development |
| 2022-2026 | > 20,000sites, > 200,000h a of *Sawah*. African wide spontaneous and rapid sawah expansion and the realization of the African Rice Green Revolution and African Rice Potential. |

## Conclusion

For a faster realization of the rice green revolution in sub-saharan Africa, there must be a starting point (reference country) to lead the rest of the region. The process should start from Ghana and Nigeria, with the rest of the countries following as illustrated in the proposed road map. The sawah eco-technology has the potential of not onlymaking sub-sharan Africa self-sufficient in rice production and ensuring food security but more importantly it ensures environmental stability.

### References

Abe S and Wakatsuki T. 2011. *Sawah* Eco-technology Triggers Rice Green Revolution in Sub-Saharan Africa, *Outlook on Agric* Vol 40, No. 3: 221-227

Ademiluyi TS. 2010. *Application of power tiller in Sawah technology for rice production in Sub-Saharan Africa: Nigeria and Ghana as case studies*, PhD Thesis, Faculty of Agriculture, Kinki University, 144 pp

Buri MM, Issaka RN and Wakatsuki T. 2009. *The Sawah System of Rice Production*, CSIR-Soil Research Institute and Kinki University, Kumasi, Ghana, pp147

Ejeta G. 2010. African Green Revolution Needn`t Be a Mirage. Science 327, 831. DOI: 10.1126/science 300: 758-762

FAO 1998. Water reports 17: *Institutional and Technical Options in the Development and Management of Small-Scale Irrigation*, Ministry of Agriculture and Fisheries, Japan and Food and Agriculture Organization of The United Nations, Rome, 145p

Hirose H and Wakatsuki T. 2002. *Restoration of Inland Valley Ecosystems in West Africa*, Nourin Tokei Kyoukai, Tokyo. 600pp

JICA 2008. Japan International Cooperation Agency: Japanese Technical Cooperation Project Studies: Impact Assessment of Rice Irrigation Projects in Sub-Saharan Africa (in Japanese), Tokyo, Japan, 62p

Kolawole K, Oladele OI and Wakatsuki T. 2011. Profitability of different sawah rice production models within lowlands in Nigeria, *J. Food, Agric Environ* (in press)

MOFA and AfDB 2008. Ministry of Food and Agriculture (MOFA) Ghana, African Development Bank (AfDB), Inland Valley Rice Development Project (IVRDP), Mid-Term Review, Final Report, Integrated Management Consultants, PAB Development Consultants, Accra, 110p

Oladele OI, Bam RK, Buri MM and Wakatsuki T. 2010. Missing prerequisite for Green Revolution in Africa: Lessons and the challenges of *Sawah* rice eco-technology development and dissemination in Nigeria and Ghana. *J. Food, Agric Environ* 8: 1014-1018

Tsujimoto Y, Horie T, Randriamihary H, Shiraiwa T, Hommaa K. 2009. Soil management: The key factors for higher productivity in the fields utilizing the system of rice intensification (SRI) in the central highland of Madagascar *Agric Sys* 100: 61-71

Wakatsuki T and Masuanga T. 2005. Ecological Engineering for Sustainable Food

Production and the Restoration of Degraded Watersheds in Tropics of low pH Soils: Focus on West Africa. *Soil Sci Plant Nutr* 51:629-636

Wakatsuki T, Obalum SE, and Igwe CA. 2011. Multifunctinality of sawah eco-technology: why sawah-based rice farming is critical for Africa's green revolution, Paper presented at 1st International Conference on Rice for Food, Market, and Development (rice-Africa), Abuja, Nigeria March 3-5, 2011

Wakatsuki T, Otoo E, Andah WEI, Cobbina J, Buri MM, and Kubota D. (eds).2001. *Integrated Watershed Management of Inland Valley in Ghana and West Africa: Eco-technology Approach*, Final Report on JICA/CRI joint study project, CRI, Kumasi, Ghana and JICA, Tokyo, 337pp

Wakatsuki T, Shinmura Y, Otoo E and Olaniyan GO. 1998. African based *sawah* systems for the integrated watershed management of small inland valleys in West Africa. *In FAO Water Report No. 17. Institutional and technical options in the development and management of small scale irrigation.* Rome, pp 45-60

Windmeijer PN and Andriesse W. 1993. *Inland Valley in West Africa: An Agro-ecological Characterization of Rice-Growing Environment*, ILRI, Wageningen, 160pp

## Challenges of Lowland Mechanization under the 'Sawah' Eco-Technology in Nigeria

Ademiluyi Y.S[1], Dada-Joel O.T[1], Olanrewaju, J.S[2], Onyemize, U.C[1], Fagbenja, M.A[1], Azogu, I.I[1] and T. Wakatsuki[3].

[1] *National Centre for Agricultural Mechanization, (NCAM), P.M.B 1525, Ilorin, Nigeria.*
[2] *New 'Sawah' Project, NCAM, Ilorin, Nigeria;* [3] *Department of Ecological Engineering, Faculty of Agriculture, Kinki University, Nara, Japan. E-mail:* segunncam@yahoo.com,

*Abstract*

The total area under cultivation and the timeliness and efficiency of accomplishing crop husbandry tasks is strongly influenced by the amount of available farm power and its efficient use. The increased usage of farm power for cultivation creates further demand for related agricultural machinery for harvesting and storage and generates employment opportunities in the agricultural service industry. It is therefore the opinion of many that due to the economic level of majority of farmers in developing countries like Nigeria, in transforming from the presently predominant hand-tool technology to a full blown large scale engine power technology, there has to be an appropriate intermediate technology. In the past this has been viewed as the animal draft technology. However, the introduction of two-wheel tractors (power-tillers) in many countries is proving to be a better and more appropriate intermediate technology. Also, it is now a wide believe and a well known fact that 'Sawah' eco-technology is a key requirement to achieving rice green revolution in Sub-Saharan Africa, to put into use the long neglected and fallowed lowland which has enormous potential and to combat environmental challenges such as flooding and global warming. The paper examines the experiences, challenges and constraints encountered in the dissemination of this proven technology and also prescribe proven methods for effective technology transfer to stakeholders, NGOs and farmers.

**Keywords:** Challenges, lowland, mechanization, power tiller, 'sawah' eco-technology.

### Introduction

Africa is the largest continent in the southern hemisphere; It has enormous ecological diversity, embracing two temperate zones, two sub-tropical zones and a tropical region. This geographical situation allows people in Africa to grow diverse crops. The 655 million Africans are agriculturally based. The main foods consist of the coarse grains (sorghum, millet, maize, wheat, rice,) and root and tuber crops (yam, cassava, sweet potato, potato, and taro). Nigeria has a total land area of 98 million hectares of which 53 million hectares is cultivable land area. Thus, agriculture in Nigeria is the most important sector of the economy from the standpoint of rural employment, sufficiency in food and fiber, and export earnings despite the subsequent discovery of oil. Available records indicate that 40% of the population of Africa (Nigeria inclusive) live below the international poverty line of US $1 per day (de Hann and Yaqub, 1998). If this figure is anything to go by, it becomes necessary to adequately address the situation.

MAP OF NIGERIA


Small-scale farmers are estimated to account for the cultivation of about 90% of the total cultivated land area in Nigeria, producing about 90% of the total agricultural output (CTA, 1997). This category of farmers still depends on manual labour to carry out their various farming operations. However, with high labour demand at critical crop production stages, coupled with high food demand for the teaming population of over 140 million, which has an annual growth rate of 2.5%, the introduction of agricultural labour saving devices to Nigerian agriculture is indispensable.

Though successive administrations in Nigeria have made concerted efforts aimed at achieving self-sufficiency in food and fibre production, these efforts have failed to achieve results. There are many factors responsible for this, a major one being the lack of an integrated and appropriate labour saving agricultural tools and machines. Therefore, the need to develop and introduce more labour saving devices on Nigerian farms in particular and in Africa South of Sahara in general, has never been more critical than now. The educated youths regard their certificates as excuses to shun farming because of the arduous nature of agricultural production activities. Knowing well that increased land productivity (greater output per unit of land) generally depends on the application of higher technology and a higher level of knowledge and management ability, crop production and processing technologies are instruments of farm management and as such, changes in mechanization level can have a multiplier effect on output per unit of land.

Per capita food production has declined in Africa for the past 30 years and farm productivity in Africa is just one-quarter of the global average. Today, more than 200 million people are chronically hungry in the region, and 33 million children under age five are malnourished. The vegetation of forest and grassland are being degraded gradually due to grievous damage andthe speed of desertification is accelerated. Natural disasters such as drought, storm of sand and dust occur frequently; water resource have decreased greatly and environment pollution has aggravated. All these impact negatively on the sustainable development of agricultural productivity.

**Reasons for decline in Per Capital Food Production in SSA**

The reasons for the declining trend in per capita food production and degrading ecological environment include:

*(i)Farmers' reality*: For many small scale farmers, the bottom line of their activities is survival. This means that decision making in food production, i.e. cropping pattern, implement choice, land tenure etc are essentially based on risk avoidance because they have very little control over either their economic or natural environments. Extremely limited alternatives exist for them.

*(ii) Mechanization:* Many farmers do not have access to the appropriate technology and inappropriate technology particularly tillage practices can quickly degrade soils, thereby, threatening a nation's productivity and food security.

*(iii) Global Warming:* Some of the factors that have led to degrading ecological environments in Africa are global warming, and the green house gas effect. Emission of carbon-monoxide (CO) from automobile exhaust, bush burning, chloro-flouro carbon (CFC) from refrigerant uses have been linked to the depletion of the ozone layer. Following this are series of floods in several low-lying countries,

excessive solar ultra violet (UV) radiation, abnormal rise in water table and destruction of rainfall pattern. All these lead to crop failure for resource-poor African farmers.

*(iv) Population Growth:* Population in Africa has grown at a faster rate than food production in the past three decades and this has led to a decline in per capita food production.

*(v)Poor Market:* Among the challenges facing accelerated food production in Africa are poorly developed markets, lack of investment, and poor infrastructure in rural areas. Despite this, there exist opportunities that can be tapped to help end chronic hunger and food problems. On the other hand, the farmer should be able not only to sell his or her produce, but to sell it at economically competitive prices. Because of the poor price polices that prevail in Africa, what could have been the farmers' profit and motivating factor to sustainably increasing production, end up in other people's pockets (middle men and consumers), hence, farmers remain with no capital to re-invest.

*(vi) Poor Extension Services:* The extension system in Africa has been more oriented to the delivery of technical messages (some of which even the extension workers themselves do not understand), with little or no regard for the needs and aspirations, let alone the reality of the farmers.

*(vii)Poor Governance*: Governance in Africa is often punctuated by coups and counter-coups. This instability leaves no room for good governance as leaders bear no genuine allegiance to the populace.

*(viii) Poor Research capability*: Research institutions in Africa are not adequately funded to have significant impact on the agricultural sector of the economy
*(ix) Poor education:* Literacy level and efforts in Africa are very low. This has slowed down adoption and adaptation of improved techniques and materials for accelerated food production.

*(x) Poor Policies and Projects Implementation*: Nigeria, has well articulated program, projects and schemes in all areas of development especially agriculture. What is lacking, however, is the sustainability of the programs.

**Raising Agricultural Productivity in SSA**

To turn things around, there is need for urgent focus on raising agricultural productivity. More investment is needed to improve soil and water management of rain-fed and irrigation agriculture, more adaptable new crop varieties, improved access to seeds and fertilizers, environmentally sustainable integrated pest management practices, reduction in post-harvest losses, and improvement of rural infrastructure, especially roads and communication infrastructure. These will need to be bolstered by bold pro-poor policies to help transform smallholder agriculture. More importantly, the following itemized points should be considered:

(i) Sustainable ecological engineering to improve environment of crops, trees and animals e.g. "Sawah".

(ii) Creation of African "Satoyama" system.

(iii) Appropriate farm equipment should be made available and affordable.

(iv) Creation and emphasis on organized marketing institutions as well as production inputs, ( e.g. co-operatives)

(v) Adequate and effective extension strategies should be put in place.

(vi) Research institutions should be strengthened, researchers encouraged and exposed, while adequate funds be released for research activities and should be made farmers 'oriented.

(vii) Agricultural policies should insulated from politics.

(viii) Workable population control measure should be put in place as well as accelerated food productivity.

(ix) Farmers insurance and guarantee should be established.

(x) Effective water management practices, fertilizers and high yielding varieties; the basic component of the green revolution and the first hypothesis of the 'Sawah' eco-technology concept, should be applied, (Wakatsuki, 2009).

**Sustainable Rice Cultivation through Sawah Eco-Technology**

Fukui (1987) pointed out that the history of rice growing in Asia has two aspects in its development processes: agronomic and engineering adaptation, though their importance differs according to rice farming ecology and the historical developmental stage of technology in each area. The agronomic adaptation challenge has almost been completely tackled through breeding, fertilizing, weeding, disease prevention and pest control. The engineering adaptation are improvements in the environment of rice growing areas by constructing and improving weirs, small reservoirs, irrigation and drainage facilities and **'Sawah'** basins, (Hirose and Wakatsuki, 2002).

Thus, the term 'Sawah' refers to man-made improvement (engineering and environmental adaptation) of rice fields with demarcated, leveled, bunded and puddled rice fields with water inlets and outlets which can be connected to various irrigation canals, ponds, springs or pumps, (Wakatsuki et al, 1998).
Total dependence on biotechnology from the standpoint that new varieties will solve rice production problems has led many people to believe that we may solve the problems by breeding, but it is also true that even the genetic characteristics of excellent species cannot show their potential fully unless fundamental environmental conditions are available. Unless biotechnology turns into alchemy or unless technology can go beyond the rule of mass balance, it will be impossible to keep the productivity of rice at a high level.

Another option is to lay emphasis on engineering technology for a better environment, such as irrigation and the creation of 'sawah' fields. It is clear that this type of engineering technology, like the one of 'sawah' based agriculture where various measures are taken to control and conserve water and land, is important in tropical Africa.

The last eco-technology strategy is to realize the importance of both agronomic and engineering adaptation technology to the development of rice growing in Nigeria in particular and Africa in general and to make sure that this technology is sustainable in rural communities as well as ecology in the region. We should understand the fact that sustainable efforts are needed to increase farming production while conserving soil and water resources in tropical Africa, where the total destruction of the agricultural environment is occurring. Therefore, 'sawah' based agriculture may be recognized as important and may be accepted in the climate of tropical Africa. The development of 'sawah' based agriculture by farmer participation in inland valleys is the first step of such efforts. Mechanization options through the supplies of small machineries are another major mile stone, but all these are not without their challenges.

**Sawah Dissemination and Lowland Mechanization in Nigeria**

The dissemination of the concept of 'Sawah' eco-technology in Nigeria is not without its challenges. These can be summarized as:

*(i) Cultural Practices:* the existing cultural practices among farmers of a particular area affect the rate at which new technology and agricultural innovations are adopted. For example, where the normal practice of the farmers who go into rice

cultivation is transplanting, they will not have difficulty in adopting 'Sawah' eco-technology. Table 1 shows the ease of adoption of 'sawah' technology based on the activeness and cultural practice of the states under consideration.

*(ii) Language Barrier:* Nigeria being a multi-lingual nation has its inherent nature of language barrier. This is the case of 'sawah' adoption in SSA in which there is no appropriate word to describe 'sawah', (Wakatsuki, 2008). Also, in Nigeria, the multi-lingual nature makes it difficult for a researcher or expert form another part of the country to disseminate his technology.

*(iii) Poverty:* the inherent poverty level of African farmers is another factor that inhibits or retards the ease of dissemination and acceptance of 'Sawah' eco-technology. Most farmers always think that new technology must be accompanied with compensation or monetary benefits before they will be able to even test a technology or adopt it. This they always do in comparison with multinational firms or communication companies who pay money for the use of their parcel of land.

*(iv) Socio-economic factors:* Important socioeconomic characteristics that are of crucial concern in the introduction of power tiller to sawah adopting farmers are age, educational level, membership of farmer group, farm size, land tenure, practice 'sawah', location/ distance of 'sawah' plot and cost of power tiller use. The effect of each of these socio-economic characteristics and their interaction will determine the trend of continuous and future use of power tillers among rice farmers. As the adoption of 'sawah' rice production technology spreads among farmers in Nigeria, the consequent effect of socio-economic characteristics on the use of power - a major component of the technology should be given serious consideration, (Ademiluyi et al., 2008)

| S/N | Geo-political zone | States | Cultural practice | 'Sawah' status |
|---|---|---|---|---|
| | South-South | Delta | Swamp rice, broadcasting | Semi-active |
| | South-West | Lagos, Ekiti, Ondo | Swamp rice, dibbling and broadcasting | Introductory stage |
| | South-East | Ebonyi, Enugu | Swamp rice, transplanting | Active |
| | North-West | Kebbi, Kaduna | Inland valley, dibbling | Active |
| | North- Central | Kwara, Niger, Benue | Inland valley, dibbling | Semi-active, Introductory |
| | North-East | Borno | Inland valley, dibbling | Non-active |

Classification of States by 'Sawah' activity and ease of adoption

### Issues on African Agricultural Mechanization

According to Tokida (2011), the following are some of the perceived issues to African agricultural mechanization

(i) No programs based on clear mechanization policy and strategy
(ii) High local production cost due to imported materials
(iii) Public led mechanization
(iv) No scale merit due to too many brands with small volume (scattered customers and small market)
(v) Unstable spare parts supply and post sales service
(vi) Very limited human resources for mechanization promotion
(vii) No international commitment to assist mechanization
(viii) No Private-Public Sector Model
(ix) No Balance in importation and domestic production
(x) No Support for farmers when purchasing machinery
(xi) No Custom hiring business model
(xii) Risks:
(xiii) Continuous economic growth?
(xiv) Maintenance of crop price at higher level
(xv) Political instability
(xvi) Effect of climate change

### Lowland Mechanization and Serif Dissemination in Nigeria and Sub-Sahara Africa

As multiple actors operate and interact in so-called systems of innovation – constituted by elements and relationships which interact in production, diffusion and use of new knowledge – one cannot ignore factors that are social, organizational, economic or perceptual, (Mele et al, 2006). There is no single terminology that covers all the different dimensions of participatory technology development, participatory research, farmer education, knowledge and information systems, farmer platforms, institutions and policies. But the term "technology transfer" will be adopted for the sake of this paper and 'Sawah' Eco-technology in general.

The failure of single blueprint method of technology transfer such as the Training and Visit (T&V) system of extension, previously promoted by the World Bank and part of the 'Transfer-of-Technology' or pipeline model of innovation which ignored that farmers are active agents and in many ways experts who have detailed knowledge of their environment (socio-economic, production circumstances, livelihood strategies) and have developed considerable knowledge concerning farming techniques (Biggs, 1990; Leeuwis, 1999) led to a wave of participatory approaches and a new cycle of learning from failures and processes. This gave rise to multiple source of innovation model as described by Biggs (1990).

**Roadmap to Mechanzation**

The following are the roadmaps to achieving agricultural mechanization in Nigeria and SSA: (i) Strategic agricultural mechanization plan and feasible SSA mechanization model, (ii) Promotion of agricultural mechanization using machines, (iii) Purchase promotion (warranty, low tariff, credit, purchase subsidy, O & M training service, etc), (iv) Promotion of service providers (loan availability, hiring entrepreneur support, mechanic training, etc.), (v) Dealer support (warranty, spare parts supply, preventive maintenance, loan availability, etc.) and (vi) Elimination of poor quality machines

**Enabling Environment for Public-Private Partnership for Mechanization in SSA**

Creation of enabling environment for agricultural mechanization to thrive involves:

(a) Government commitment with clear mechanization policy and strategy with concerned ministries
(b) Direct public investment that does not disturb private investment
(c) Available human resources
(d) Reduction of business risks
(e) Business system for sustainable agricultural inputs
(f) Protection of investors
(g) Tariff reduction
(h) Cost reduction through subsidies
(i) Creation of mechanization demand
(j) Protection of customers
(k) Financial support and purchase subsidies

**Promotion of 'Sawah' Eco-Technology and Rice Farming (SERIF)**

The 'Sawah' technology for rice production as an action research system can be actively disseminated and replicated in the 36 states of Nigeria and SSA in general through:

(a) Awareness seminars and workshop for all stakeholders in the agricultural sector.

(b) Active collaboration between various governmental and non-governmental organizations interested in the development of agriculture.
(c) Organization of Introductory Training of Trainers workshop.
(d) Demonstration of the technology to selected leading farmers in each state.
(e) Active participation of farmers and farmer to farmer training.
(f) Periodic training and retraining on 'Sawah' technology.
(g) Periodic monitoring and evaluation of the technology.
(h) Participatory Learning and Action Research (PLAR)

Currently, various mainstream agricultural research and development projects use new methods, such as Farmer Field Schools (FFS) and Local Agricultural Research Committees (CIALs), for interacting with smallholder farmers to develop and spread appropriate technologies (Bentley et al., 2006; Braun et al., 2000). These methods envision participatory learning and action research and rely on engaging people in experimentation, observation, measurement and other activities which allow people to draw their own conclusion. PLAR equally aims to promote technological and organizational change through improving farmers' capacity to observe, to exchange knowledge, experiences and practices, and to make informed decisions.

**References**

Ademiluyi, Y.S., O.I. Oladele and T. Wakatsuki. 2008. Socio-economic factor influencing power tiller use among 'sawah' farmers in Bida. Journal of Food, Agriculture & Environment Vol.6 (3&4): 387-390.

Bentley, J.W., S. Priou, P. Aley, J. Correa, R. Torres, H. Equise, J.L. Quiruchi and O. Barea. 2006. Method, creativity and CIALs. International Journal of Agricultural resources, Governance and Ecology 5: 90 - 105.

Biggs S.D. 1990. A multiple source of innovation model of agricultural research an technologypromotion. World Development 18: 1481 - 1499

Braun, A.R., G. Thiele, and M. Fernandez. 2000. Farmer field schools and local agricultural research committees: complimentary platforms for integrated decision-making in sustainable agriculture. AgREN Network Paper 105

CTA, (1997). Report of the seminar on Integrating Mechanization in Sustainable Agricultural Development Strategies. Organized by the Technical Centre for Agricultural and Rural Co-operation (CTA), in Burkina Faso, 24 - 29 November, 1997. P 218 - 221.

de Hann, A. and Yaqub, S. (1998). What is known about identifying the poor in Africa and the Middle East? Paper presented at workshop on Building and sustaining the capacity for social policy reform; Morocco, Mimeo. Poverty.Research Unit, University of Sussex, Brighton, UK.

Fukui H. 1987. Ecology and Types of Technology Adapted, In Watabe T., Y. Takaya, K. Tanaka and H. Fukui (eds), *History of Asian Rice Culture, vol. 1,* Ecological Bases of Asian Rice Farming Culture . Technology and Ecology, p 277 – 331, Shogakukan, Tokyo Hirose, H. and Wakatsuki T. 2002. Restoration of Inland Valley Ecosystems in West Africa, Nourin Tokei Kyoukai, Tokyo. 600pp

Leeuwis C. 1999. Integral Technology design as a process of learning and negotiation: A social science perspective on interactive prototyping, p 123 -143, In C. Leeuwis (ed.), Integral Design: Innovation in Agriculture and Resource Management. Mansholt Institute, Wageningen University, The Netherlands.

Mele, V. P., A.K.M. Zakaria, Hosne-Ara-Begum, Harun-Ar-Rashid and N.P. Magor. 2006. Videos that strengthen rural women's capability to innovate. Journal of Communications for Development and Social Changes.

Tokida Kunihiro, 2011. "Public-Private Sector Models for Mechanization in SSA", Paper presented at the Workshop on Boosting Agricultural Mechanization of Rice Cropping System in Sub-Saharan Africa, St Louis, 6-8 June, 2011

Wakatsuki, T., Shinmura, Y. Otoo, E., and Olaniyan. 1998. 'Sawah' system for integrated watershed management of small inland valleys in West Africa, In FAO Ed., Water Report No 17, Institutional and Technical Options in the Development and management of Small Scale Irrigation, 45 – 60, FAO, Rome

Wakatsuki, T. and Buri, M.M. 2008. General Concept of 'sawah' system, In Buri M.M., R.N. Issaka and T. Wakatsuki (eds.), The "Sawah" system of Rice Production, Kumasi, Ghana

Wakatsuki T., Buri M.M and Oladele O.I. 2009. West Africa Rice Green Revolution by 'Sawah' Eco-technology and the creation of African Satoyama system. Kyoto working papers on Area studies No. 63 (G-COE Series 61), Kyoto, Japan

# The Integrated Analysis of the Introduction of Land Reclamation ("Sawah" Development) of Inland Valleys by using the Power-Tiller in Ashanti Region, Ghana.

Naoyoshi Kawano

*Japan International Research Centre for Agricultural Sciences, Tsukuba, Ibaraki, Japan*

**Abstract**

JIRCAS DIITRPA Project has studied the land development at farmers' level to increase rice production in Ghana since 2009. The main concept of our project is land reclamation by using the power-tiller, introduction of irrigation system at farmers' level and cultivation method for high yielding rice under personal irrigation system. The above concept has been practiced in Asia, which resulted in the achievement of enough rice in some countries in Asia. However, the practice of the above concept has not yet been expanded in Africa. Therefore, there is the need to verify the present situation where the concept is put into practice in farmers' fields in Africa. Secondly we should then study how to put the concept into practice effectively and sustainably. In 2009, the technologies of "Sawah" were extended to 12 extension workers and concerned farmers at 9 sites in 4 communities through On-the-job training, by researchers of Soil Research Instite (SRI) and Crops Research institute (CRI), both of the Council for Scientific and Industrial Research (CSIR), Ghana. In 2010, the trained extension workers and farmers developed fields at 11 sites in 8 communities. Data on cost and working hours for development of the fields and rice cultivation was collected through those activities. Evaluation of development of fields and rice cultivation was done. In 2011, data collection and evaluation was done continuously. Some project sites showed successful development of fields and rice cultivation as a business, whilst others did not. The gap between successful sites and unsuccessful sites was analyzed to find out constraints including physical, economical, social and institutional factors. Constraints to expanding the technology are as a result of one or a combination of these factors.

## Introduction:

JIRCAS DIITRPA Project has studied the land development at farmers' level to increase rice production in Ghana since 2009. The main concept of our project is land reclamation by using the power-tiller, introduction of irrigation system at farmers' level and cultivation method for high yield rice production under the personal irrigation system. The above concept has been practiced in Asia, which resulted in the achievement of enough rice production in some countries in Asia. However, the practice of the above concept has not yet been expanded in Africa. There was therefore the need to study the current situation and how the concept can be, effectively and sustainably, put into practice in farmers' fields in Africa

Currently, rice is the second most staple food after maize in Ghana. Moreover its consumption keeps increasing, because of population growth, urbanization and change in consumer habits. The food supply quantity of milled rice was 28 kg per capita per year in 2007 (FAO STAT), which resulted in the consumption of 616,000 tons of milled rice. However, rice production in Ghana was estimated at 148,272 tons (milled rice) in 2007 (FAOSTAT). Ghana could not produce enough to meet its national requirement. Currently, Ghana produces less than 40% of its national requirement. Therefore increase in rice production is an urgent issue for food security.

The potential of rice production is higher in lowlands (irrigated paddy field, 3.7 ~ 6.8 t $ha^{-1}$, rain-fed lowland, 2.5 ~ 4 t $ha^{-1}$) than in upland (< 2 t $ha^{-1}$), because of better accessibility of water, less degradation of soil, and continuous fertilization through overflow from rivers (Nguyen, 2000). Rice production in inland valleys in West Africa is mostly under rain-fed ecosystem, which results in flooding or shortage of water, even though a lot of water may be available. In natural condition, a small stream flows in the lowest part in most of inland valleys. However the water is not used for rice cultivation effectively, which constraints the attainment of high yield. Therefore, irrigation system is one of the most important methods to increase rice production. In this study, the introduction of simple water delivery system by farmers ("Sawah" system) into farmers' field was focused. The problems and strategies of expanding the "sawah" system were studied.

**Methodology**

In 2009, the "Sawah" technology was transferred to 12 extension workers and selected farmers at 9 sites in 4 communities through on-the-job training (OJT) training by researchers of SRI and CRI. In 2010, the trained extension workers and farmers further developed fields at 11 sites spread across 8 communities. Data on cost and working hours for development of the fields and rice cultivation was collected. The evaluation of the development of fields and rice cultivation was done. In 2011, the above data and evaluation was done silmultaneously. This involves the construction of canals, dykes, bounds etc. for water delivery. The process of development was as follows:

*a) Clearing and de-stumping:*

Clearing weeds, big stones, and de-stumping the root of trees is very important activities for developing inland valley because of the usage of the power tiller for ploughing. Any left-over roots of trees may damage the power tiller during ploughing. Labour was hired for these activities because the work was new to farmers and was supposed to be done within a limited period.

*b) Ploughing:*

Under rain-fed ecosystem, the land is rarely ploughed. Under this study land was ploughed using the power tiller (Yanmar 11 ps or Shackti) for effective soil management, weed control, levelling, etc. The operator for the power tiller was hired. Ploughing started after rainfall when the soil was soft

*c) Bund canal, dyke/weir and pond construction*

Bunds were constructed around field for the submergence of the field, for easy levelling. The fields were further divided into small plots, based on the micro-topography of the site. Canal, dykes and ponds were constructed at the same time. Dykes were constructed simply by using existing materials ( woods and sandbags) for easy repair by farmers when it gets damaged. Labour was hired for the whole of the above activities.

*d) Virgin land ploughing, puddling and levelling*

Puddling was done by crashing the soil with a power tiller. After puddling, the field was submerged for levelling. A motor pump was used for the submergence of the field in Nsutem site because the water should not be delivered by gravity. Power tiller was used for the puddling and levelling. An operator was hired for the operation of the power tiller.

*e) Cultivation of rice*

Rice cultivars used were Sikamo (resistance to drought and developed by CRI), Jasmine 85 and Lapers (perfumed rice). Seed was sowed on a dry bed nursery. Three weeks after nursing, seedlings were transplanted at a spacing of 20 cm x 20 cm. Basal fertilizer (60 kg/ha each of N, P, K) was applied a week after transplanting and topdressed with 30 kg/ha N at panicle initiation stage. Weeding was done several times either manually or use of herbicide. Agrochemicals were used for diseases and insects control. Harvesting was done manually.

*f) Yield component analysis and rice product*

Three locations were selected in each farmers' field for sampling. All rice in a square meter was harvested from 5 plots in each field. Average tiller number and panicle number were determined from the rice harvested from a square meter area from each plot. Number of grains per panicle and number of filled grains were measured for each panicle. Percent ripened grains was calculated by dividing the number of total grains by actual product harvested from field.

*g) Visual evaluation of soil, water, disease, weeds, and plant growth conditions*

Visual evaluation of soil, water, diseases, weed and plant condition was done at the heading stage in each plot in each farmer's field. Each condition was categorized into three categories into good, not bad and bad (Table 1).

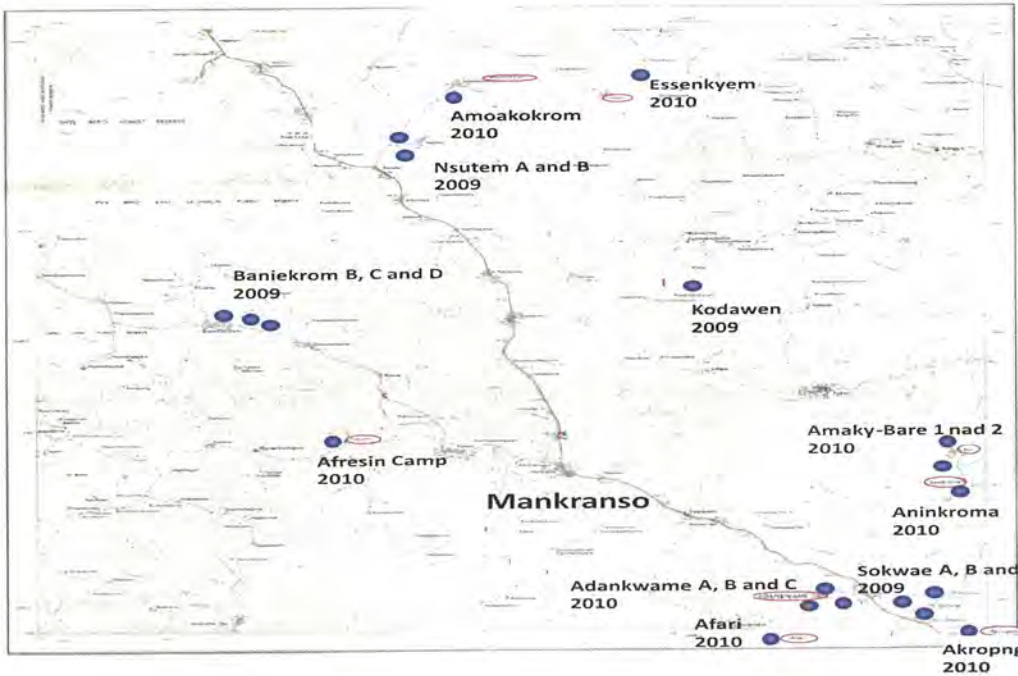
*h) Social, economic and institutional factors to rice production*

These factors were analyzed by administering questionnair to farmers at the Project sites. Informationa gathered included the following.

I) Social factors (Origin of farmer, own house or not)
ii) Technical factors (Experience of rice cultivation, knowledge of rice cultivation)
iii) Economical factors (Main income, important crop for farmer, income a year)
iv) Institutional factors (Number of extension workers visiting farmers' field, age of extension worker, degree of recognition of block farmer system)

Table 1. Visual evaluation of soil, water, diseases, weeds and plant condition

| Item | Good | Not bad | Bad |
|---|---|---|---|
| Water | Field flooded at aedequate water depth | Soil is moist but field not flooded at adequate water depth | Soil is dry |
| Soil | Clour is black. Soil is clayey | Colour is black but soil is sandy. Colour is red or white in some parts of the field | Colour is red or white. Soil is sandy |
| Weeds | No weeds in field | Weeds can be observed near the field | Weeds can be obserded easily |
| Diseases | No diseases observed | Deseases can be observed near the field | Diseases can be observed easily |
| Plant growth | Yield estimates of > 4 t $ha^{-1}$ | Yield estimaters of between 2 - 4 t $ha^{-1}$ | Yield estimates of < 2t $ha^{-1}$ |




**Results and Discussion**:
Some project sites showed the successful development of fields and rice cultivation as a business, but others did not. The gap between successful and unsuccessful sites was analyzed to find out whether constraints were physical, economical, social or institutional factors. Suggestions to overcoming these constraints whether single or a combination are presented and discussed below.

*(a) Yield component analysis*
Figure 2 shows the result of estimated yield at the project sites. There is a large yield gap of 4.9 t $ha^{-1}$ from (3.0 t $ha^{-1}$ to 7.9t $ha^{-1}$) among the sites. To understand the reasons for the yield gap, multi regression analysis was done. The result is as shown in the following formula: **Y (yield) = 0.374 $X_1$ x 0.420 $X_2$ x 0.613 $X_3$ x 0.328 $X_4$**, $R^2$ = 0.648 where $X_1$: number of panicle/area, $X_2$: number of grains/panicle, $X_3$: ratio of matured grains, $X_4$: weight of grain

Firstly, the ratio of matured grains affected yield. Secondly number of grains per panicle also affected yield, indicating that the number of matured grains per unit is important for high yield. The relationship between number of matured grains and yield was significantly correlated (Figure 4).

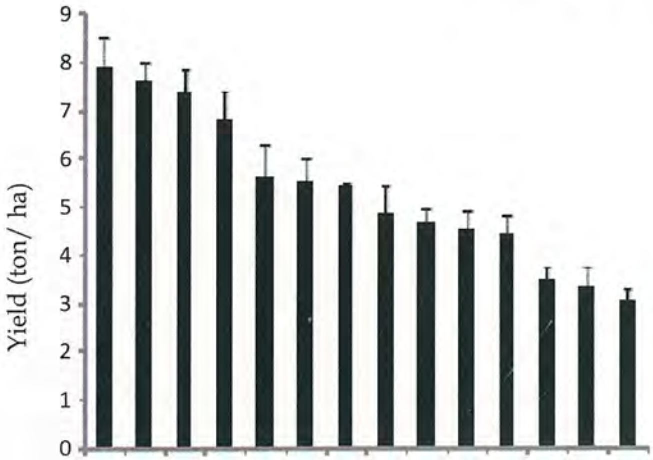



Fig. 2. Grain yield (t $ha^{-1}$) at various sites

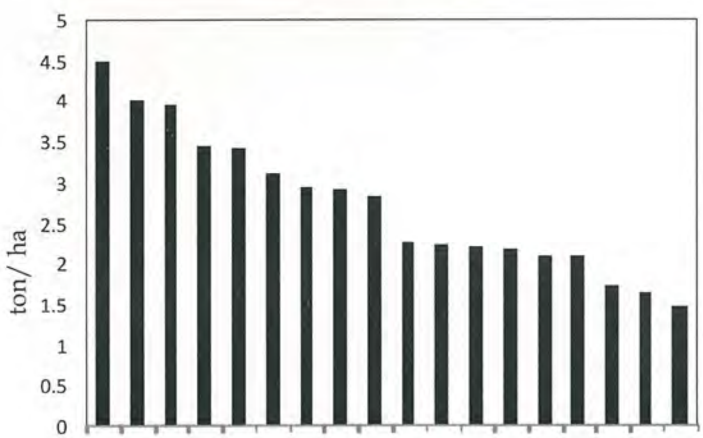



Fig. 3. Grain yield per unit area (1 ha) at the various sites

Figure 3 shows the actual production in project sites. There is a large yield gap from 1.5 - 4.5 t $ha^{-1}$. Among the sites also the result showed the gap between the estimated yield and actual products, which is discussed later. "Sawah" technology improves rice production above 4 t $ha^{-1}$ (Buri et al. 2011). However rice production of some project sites was very low. It is therefore important to find out the reasons for such yield gap among farmers in order to expand "sawah" technology.

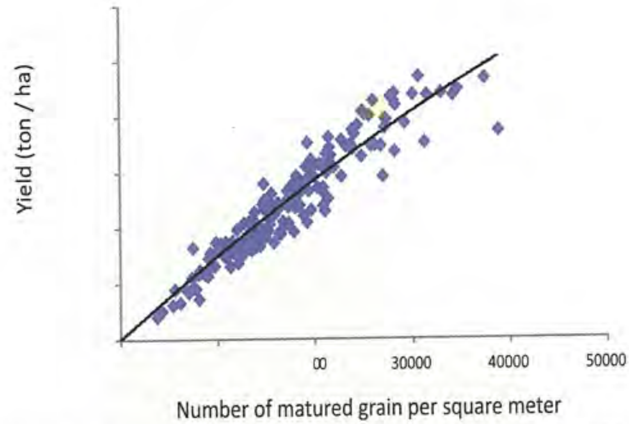



**Fig. 4.** Relationship between number of matured grain and grain yield.

*(b) Visual evaluation of soil, water, disease, weeds, and plant growth condition*

Table 2 shows the correlation coefficient between each item of evaluation and number of matured grain per unit. Water condition, weed management and plant growth condition at ripening stage affected the number of matured grain. Management of rice cultivation at ripening stage is therefore critical and important for obtaining high yield.

Actual product =

$R^2 = 0.60$

1.05 (X1) Origin of farmers
x
0.12 (X2) Own house or not
x
-0.09 (X3) Experience of rice cultivation
x
0.12 (X4) Knowledge of rice cultivation
x
0.59 (X5) Main income is rice or not
x
0.21 (X6) Important crop for farmer
x
0.1 (X7) **Income a year**
x
0.02 (X8) Times of extension officer visiting the farmer's field
x
0.83 (X9) Age of extension officer
x
0.16 (X10) Degree of recognition of Blok farmer system

Red letter indicates significant correlation at 5%

**Table 2.** Relationship between selected factors and number of filled grains

| Parameter | Correlation co-efficient |
|---|---|
| Water | 0.517 |
| Soil | 0.249 |
| Weed | 0.486 |
| Disease | 0.03 |
| Plant growth | 0.59 |

*(c) Social, economic and institutional factor to rice production*

The effect of social, economic and institutional condition on rice cultivation was studied based on the questionnaire administered to farmers at the project sites. Quantification analysis was then done. Coefficient of origin of farmer and age of extension workers were high (Figure 4).

Major constraint of rice production is poor water management and inherent low fertility (Buri and Wakatuki 1996, Buri et al. 1998 and Issaka et al. 1996 a, b). To improve rice production "Sawah" technology is effective, because the field is bunded, puddled and levelled with inlet and outlets canal at farmers' level (Buri et al. 2011). In our project sites, estimated yield was 3.0 - 7.9 t $ha^{-1}$ (Figure 1), which is higher than that of rain-fed rice cultivation in inland valley in Ghana (2.4t $ha^{-1}$). However, there was a large gap among farmers. Generally differences in the quantities of applied fertilizer caused this gap. Yield component analysis showed that number of matured grain affected the yield significantly (Figure 3). Number of matured grain is determined at ripening and maturity stages. Water and solar radiation during above stages affected yield. In this study, water condition at ripening stage significantly correlated with number of matured grains (Table 2). Therefore, it is suggested that practical level of water management by farmer affects yield. Actually, soil is only kept moist but fields are not flooded in most farmers' field during the ripening stage. In Ghana, most farmers are familiar with upland irrigation. Therefore farmers do not normally keep water in the field even though they know that water is important for rice at the ripening stage.

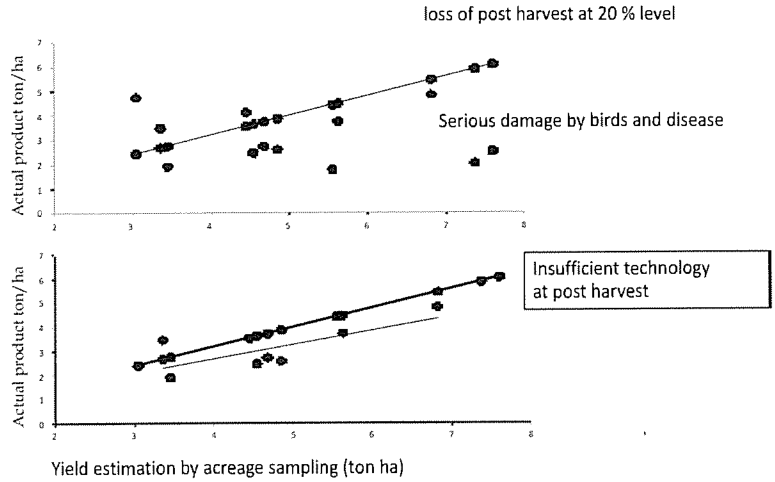



Fig. 5. Gab between actual and estimated yield.

Also the gap between estimated yield and actual product was observed. Figure 5 shows the relationship between estimated yield and actual product. Generally, post harvest losses bewteen 10 - 20% are considered nornal. In Ghana, post harvest losses varied from 40 - 50% at most project sites except a few. Post harvest losses are partly caused by delay in harvesting and wettening of grain by rain at project sites. It is necessary to improve post-harvest technology and reduce lossess.

"Sawah" technology is accompanied by investment in the land because of effective land preparation. In Ashanti region, most of rice farmers migrated from the northern parts of the country and do not own land. Migot-Adholla et al. (1990) revealed that, the investment behaviour of farmers depends on the security of land tenure. Thus, farmers are considerably more likely to improve lands they own, or for which they have long-term use rights, than lands they operate under short-term use rights. Therefore, issue of land is very important to expand "Sawah" technology. In this study, origin of farmer had a significant relationship with rice produced (Figure 4). Those farmers who own land or right of land use for long term had higher yield. To recover invested funds, it is necessary to use land for long term. In future, it is very important that farmers have land use stability in order to expand "Sawah" technology.

Generally, investment is accompanied by the risk. It is natural that farmers feel the risk for investment under rice cultivation. If farmers cultivate rice under the "Sawah" technology properly, the risk is lower. However, if farmers do it by inappropriate ways, the risk becomes higher. The role of the extension worker is a key factor in expanding the "Sawah" technology. If extension workers teach farmers the "sawah" technology properly, farmers will be able to get the desired results. In this study, age of extension worker had a significant relationship with product, which suggests that the amount of knowledge and experience of rice cultivation of extension workers contributed to improve rice products of farmers.

## Conclusion

From this study it is important to take note of the following for the future expansion and rapid adoption of the"Sawah" technology: (i) understanding water management, (ii) improving post-harvest technology, (iii) stable and long-term land tenure is necessary to recover investment and (iv) the extension worker is a key factor in technology out-scaling activities.

## Reference

Africa Rice (1998) Agriculture in Africa, Africa Rice Centre (Africa Rice Annual report. Cononou, Republic of Benin.

Buri M. M., Issaka R.N., Wakatsuki T., Kawano N., 2011. Improving the productivity of lowland soils for rice cultivation in Ghana: The role of "Sawah" system, J. Soil Sci. Environ. Manage. Vol. 2 304-310

Buri M. M, Masunaga T., Ishida F., Kubota D., Wakatsuki T. 1998 Soils of flood plains in West Africa: General fertility status. Soil Sci. Plant Nutr. 45: 37-50

Buri M. M. Wakarsuki T. 1996, Soils in flood plain in West Africa: Geographical and Regional distribution of some soil fertility parameters. Proceedings of the International Symposium on "Maximizing Sustainable Rice Yield through Improved Soil Environment Management, Khon Kaen, Thailand, 1 445-455

Issaka R. N, Masunaga T, Kosaki T, Wakatsuki T (1996a). Soils of Inland Valleys of West Africa: General fertility parameters. Soil Sci. Plant Nutr. 42: 71-80.

Issaka R. N, Masunaga T, Wakatsuki T (1996b). Soils of Inland Valleys of West Africa: Geographical Distribution of Selected Soil Fertility Parameters. Soil Sci. Plt. Nutri., 42: 197-201.

Migot-Adholla SE, Hazell P, Blarel B, Place F (1990). Indigenous land rights systems in Sub-Saharan Africa: A constraint on productivity? World Bank Econ. Rev., 5: 155-175.

Wakatsuki, T. Buri M. M., and Fashola, O. O. 2004: Rice green revolution and Restoration of Degraded Inland Valley Watersheds in West Africa through Participatory and Self-Support "Sawah" Development, In Participatory Strategy for Soil and Water Conservation, ERECON, Institute of Environment Rehabilitation and Conservation, 241-246

# "Sawah" Rice System: A Technology for Sustainable Rice Production in Ebonyi State of South-eastern Nigeria

J. C. Nwite[1], S. I. Obalum [2], C. A. Igwe[2], E. N. Ogbodo[3] and T. Wakatsuki[4]

*[1] Department of Crop Production, Federal College of Agriculture, Ishiagu P.M.B. 7008, Ivo L.G.A, Ebonyi State, Nigeria; [2] Department of Soil Science, University of Nigeria, Nsukka, Nigeria; [3]Department of Soil and Environmental Management, Ebonyi State University, Abakaliki; [4] Faculty of Agriculture, Kinki University, Nara 631-8505, Japan.*
*E-mail:* johnwhite4real_2007@yahoo.com

**Abstract**

The soils in Ebonyi State agro-ecological zones of south-eastern Nigeria are plagued with characteristics that impede optimal crop production. Failures in agricultural development in this part of south-eastern Nigeria may have been caused by the inability of the farmers to develop the abundant inland valleys for such crops like rice using appropriate water management systems. In order to arrest the declining productivity of the inland valley soils in these zones, four different organic sources (Rice husk; Rice husk ash; Poultry droppings at 10 t/ha and N.P.K 20:10:10 at 400 kg/ha) were used in four different 'sawah' environments including farmers environment (complete 'sawah'; incomplete 'sawah'; partial 'sawah' and farmer's environment) in two inland valleys in south-eastern Nigeria to evaluate their effects on some soil properties and rice grain yield. '*Sawah*' is generally associated with controlled water management in the field where the soil is expected to be puddled, levelled and bunded in order to impound water provided by rain water or by rise in the level of a river in an inland valley. Soil properties tested were soil organic carbon, total nitrogen, pH, CEC, EA, Base saturation, bulk density and total porosity while the grain yield of rice was also measured. The results showed that soil pH, OC, TN, bulk density and total porosity were statistically improved within 'sawah' managed environment at both locations. The amendments also improved the pH, TN, CEC, base saturation and soil total porosity during the period. Rice grain yield was statistically increased by both 'sawah' managed environments and the soil amendments, with complete 'sawah' environment amended with poultry droppings giving the highest yield of 7.5 tons per hectare.

**Key words:** rice grain yield, 'sawah' environment, soil, amendments, soil properties.

## Introduction

Increasing food production both to meet in-country requirements and to help the world overcome food crisis is one major issue facing Nigeria today. In spite of the potentials of Nigeria inland valleys especially the Southeast for Agricultural use, these areas are yet to be exploited fully. Poor soil fertility and inefficient weed and water control are the major constraints to proper utilization of these inland valleys for sustainable rice-based cropping. The soils of South-eastern Nigeria particularly, Ebonyi State are low in fertility. The soils have been noted to be acidic, low in organic matter status, cation exchange capacity and other essential nutrients (Enwezor *et at*, 1988; Asadu and Akamigbo, 1990; Nnabude and Mbagwu, 1999; Ogbodo and Nnabude, 2004). Rice production is the major cropping operation in both Ebonyi Central and South agro-ecological zones of the South-eastern Nigeria. The crop is poised with the problem of realizing production owing to the soil fertility, weed and water management problems.

Determining appropriate fertility, weed and water management practices could lead to improved and sustainable crop yields in these areas. An African adaptive '*sawah*' lowland farming with small scale irrigation scheme for integrated watershed management will be the most promising strategy to tackle these problems and restore the degraded inland valleys in these areas for increased and sustainable food production (Nwite *et al*, 2011). With the introduction of the 'sawah' rice production technology to Nigeria in the late 1990s and its high compatibility with our inland valleys, the place of these land resources in our agricultural development in this South-eastern Nigeria and realization of green revolution is increasingly becoming clearer (Obalum *et al;* 2010). However, most farmers do not know much about the rudiments or fundamentals of this technology. 'Sawah' involves bunding, puddling and levelling, with provisions for inlet and outlet channels on the bunds for irrigation and drainage. Construction of canals which could be receptive (point of collection of flowing water from adjacent uplands) and linked to water source(s) in the field (rivers, dams or streams) are also involved in this technology. The benefit of bunding is that it ensures water is regulated in the field at all times during the growing period of the crop.

On the other hand, puddling aspect of this technology aims at complete destruction of the soil structure, which could lead to reduction in macro pores numbers, hence, increase in the microspores numbers that help to reduce deep percolation losses of water in the inland valleys. Therefore, it is important to note that the rice field environment determines good management of fertility, weed and water. Andriesse (1998) noted that in order to realize and sustain the potential benefits accruable from cultivating the inland valleys of West Africa, much of the research effort in these land resources is geared towards alleviating productivity constraints. This study is aimed at bridging the gap in knowledge of appropriate inland valleys and '*sawah*' technology development in Nigerian lowlands among the farmers.

## Materials and Methods

*Site description*

The study was conducted on the floodplains of Ivo River in Akaeze, Ebonyi South and Oyolo River in Igweledoha, Ebonyi Central, both in Ebonyi State of South-eastern Nigeria. Akaeze lies at approximately latitude $05^0 56^{/}$ N and longitude $07^0 41^{/}$ E. Annual rainfall is 1,350 mm spread from April to October with average air temperature of 29°C. Igweledoha on the other hand, lies within latitude $06^0 08^{/} 40^{//}$ N and longitude $08^0$ $06^{/}$ $35^{//}$ E. The two sites are within the Derived Savannah vegetation zone. The soils are described as Aeric Tropoaquent (USDA 1998) or Gleyic Cambisol (FAO 1988). The soils have moderate soil organic carbon (OC) content on the topsoil with low pH and cation exchange capacity (CEC). Soils are mainly used for rain-fed rice cultivation and vegetable production as the rains recede.

*Field Development*

The field in each location was divided into four different main plots where the four rice growing environments were created. Composite soil samples were collected at 0- 20 cm depth at the 2 locations for initial soil analysis. Out of the four main plots, three were demarcated with 0.6 m raised bunds. In these plots, water was controlled and maintained to an approximate level of between 5 cm to 10 cm from 2 weeks after transplanting to the stage of ripening of the grains, while in the other plot without bunds (which represent the traditional field), water was allowed to flow in and out as it comes. The four rice growing environments which represented the 4 main treatments include: (a) Complete 'sawah': bunded, puddled and leveled rice field (CS), (b) Incomplete 'sawah': bunded and puddled with minimum leveling rice field (ICS), (c) Partial 'sawah': bunded, no puddling and leveling rice field (PS) and (d) Farmers environment: no bunding, puddling and leveling rice field (FE). The complete and incomplete 'sawah' fields were tilled with power-tiller according to the specification of environment. The other plot was manually tilled. This was followed by the demarcation of each of the main plots into five subplots with other raised bunds, which were treated with soil amendments. In each of the sub-plots, the following treatments were arranged as a split-plot in a randomized complete block design (RCBD). These sub-plots were: (i) Poultry droppings (PD) @ 10 t $ha^{-1}$, (ii) NPK fertilizer-20:10:10 (F) @ 400 kg $ha^{-1}$ recommended rate for rice in the zone, (iii) Rice husk ash (RHA) @ 10 t $ha^{-1}$ obtain within the vicinity, (iv) Rice husk (RH) @ 10t $ha^{-1}$, also obtained within the vicinity, and (v) Control (CT) with no soil amendment. Each treatment was replicated three times and each sub-plot was 6 m x 6 m. The PD, RHA and RH were spread on the plots that received them and incorporated manually into the top 20 cm soil depth 2 weeks before transplanting.

The nutrient contents of these organic amendments were determined (Table 2).

The test crop was a high-tillering rice variety *FARO 52 (WITA 4)*. The rice seeds were first raised in the nursery and later transplanted to the field after 3 weeks in nursery. At maturity, rice grains were harvested, dried and yield computed at 90% dry matter content. At the end of harvest, soil samples were collected from each replicate of every plot from each of the location for chemical analyses.

*Laboratory methods*

Soil samples were air-dried and sieved with 2 mm sieve. Soil fractions less than 2 mm from individual samples were then analyzed using the following methods. Particle size distribution of less than 2 mm fine earth fractions was measured by the hydrometer method as described by Gee and Bauder (1986). Soil pH was measured in a 1:2.5 soil to water ratio and 0.1 M KCl suspension. The soil OC was determined by the Walkley and Black method described by Nelson and Sommers (1982). Total nitrogen was determined by semi-micro kjeldahl digestion method using sulphuric acid and $CuSO_4$ and $Na_2SO_4$ catalyst mixture (Bremner and Mulvaney, 1982). Exchangeable cations were determined by the method of Thomas (1982). CEC was determined by the method described by Rhoades (1982), while exchangeable acidity (EA) was measured using the method of McLean (1982). Base saturation was calculated as the percentage ratio of total exchangeable bases to effective cation exchange capacity, using the procedure outlined in Tropical Soil Biology and Fertility Manual (Anderson and Ingram, 1993). Core samples were allowed to drain freely for 24 hours before being oven dried for determination of bulk density by the Blake and Hartge's (1986) method. Total porosity was calculated as: 1 – *(the determined bulk density/an assumed particle density of 2.65 mg/m$^3$) x 100 (%).*

*Data analysis*

Data analysis was performed using **GENSTAT**. Significant treatment means was separated and compared using Least Significant Difference (LSD) and all inferences were made at 1% and 5% levels of probability.

**Results and Discussion**

(a) *Effect of 'sawah' field growing environment and soil amendments on the soil pH, organic carbon and nitrogen on 0-20 cm topsoil*

Table 3 shows that soil pH statistically differed ($P < 0.05$) among the 'sawah' field environments in the two locations with complete 'sawah' field environment having the highest value of 4.91, while the lowest was recorded in the farmer's field environment (4.71) in Akaeze and 4.87 – 4.74 in complete and farmer's fields, respectively at Igweledoha location . The pH condition for the soil also showed significant difference among the amendments at ($P < 0.001$) in both sites with RHA in complete 'sawah' field having the highest values. This results agreed with Nwite *et al.* (2008 and 2011), that proper and well – managed water in inland valley rice field, and also use of ash materials will improve pH, thus enabling good soil environment for plant nutrition.

The amendments significantly ($P < 0.001$) affected soil OC in the 'sawah' environments in both locations with RH recording the highest values in all the environments. The result also indicates that OC was equally significantly improved at ($P < 0.05$) with complete 'sawah' environment giving the highest values at both locations. The result concurs with the findings reported by Rasmussen (1999).

**Table 1:** Some properties of the topsoil of the experimental plots (0-20 cm) before tilling and application amendment

| Soil property | Igweledoha | Akaeze |
|---|---|---|
| Clay (%) | 17 | 10 |
| Silt (%) | 39 | 21 |
| Sand (%) | 44 | 69 |
| Textural class | L | SL |
| Organic matter (%) | 1.67 | 2.64 |
| Organic carbon (%) | 0.97 | 1.61 |
| Total Nitrogen (%) | 0.056 | 0.091 |
| pH (water) | 3.7 | 3.6 |
| pH (KCl) | 2.6 | 3.0 |
| Sodium {cmol (+) $kg^{-1}$} | 0.27 | 0.15 |
| Potassium {cmol (+) $kg^{-1}$} | 0.13 | 0.04 |
| Calcium {cmol (+) $kg^{-1}$} | 1.6 | 1.0 |
| Magnesium {cmol (+) $kg^{-1}$} | 1.0 | 0.6 |
| Cation Exchange Capacity (C.E.C) | 11.2 | 5.6 |
| Exchangeable Acidity (E.A) {cmol (+) $kg^{-1}$} | 2.0 | 3.2 |
| Available P (mg $kg^{-1}$) | 7.83 | 4.20 |
| Base saturation (%) | 26.79 | 24.76 |
| Bulk Density (g $cm^{-3}$) | 1.49 | 1.44 |
| Total Porosity | 43.77 | 45.66 |

Table 2: Nutrient compositions (%) in the amendments

| Property | Amendment | | |
|---|---|---|---|
| | Poultry Dropping (PD) | Rice Husk (RH) | Rice Husk Ash (RHA) |
| OC | 16.52 | 33.75 | 3.89 |
| N | 2.10 | 0.70 | 0.056 |
| Na | 0.34 | 0.22 | 0.33 |
| K | 0.48 | 0.11 | 1.77 |
| Ca | 14.4 | 0.36 | 1.4 |
| Mg | 1.2 | 0.4 | 5.0 |
| P | 2.55 | 0.49 | 11.94 |
| C: N | 7.9 | 48.2 | 6.7 |

Hirose and Wakatsuki (2002), and Tebrugge *et al.*, (1999), that crop residues in a soil layer significantly influence soil OC using different ploughing methods and it also relates to adjacent upland debris and materials feeding the inland valleys with a corresponding addition of OC in the 'sawah'-managed system.

**Table 3:** Effect of '*sawah*' field growing environment and soil amendments on selected topsoil (0-20cm) characteristics

| Amendment | Sawah Environment | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Complete | | | Incomplete | | | Partial | | | Farmers Environ. | | |
| | pH | OC | N | pH | OC | N | pH | OC | N | pH | OC | N |
| Akaeze Site | | | | | | | | | | | | |
| PD | 4.9 | 1.37 | 0.09 | 4.8 | 1.38 | 0.10 | 4.9 | 1.24 | 0.08 | 4.7 | 1.06 | 0.08 |
| NPK | 4.9 | 1.44 | 0.10 | 4.8 | 1.13 | 0.09 | 4.7 | 1.31 | 0.07 | 4.6 | 1.06 | 0.07 |
| RHA | 5.2 | 1.33 | 0.08 | 5.1 | 1.12 | 0.07 | 4.9 | 1.06 | 0.08 | 4.8 | 1.0 | 0.07 |
| RH | 4.9 | 1.50 | 0.10 | 4.9 | 1.30 | 0.07 | 4.8 | 1.72 | 0.07 | 4.9 | 1.13 | 0.06 |
| CT | 4.7 | 1.09 | 0.06 | 4.5 | 0.91 | 0.06 | 4.6 | 0.70 | 0.06 | 4.5 | 0.78 | 0.05 |
| Mean | 4.9 | 1.34 | 0.08 | 4.8 | 1.21 | 0.08 | 4.8 | 1.21 | 0.07 | 4.7 | 1.01 | 0.07 |
| LSD (0.05) | 0.11 | 0.21 | 0.01 | 0.11 | 0.21 | 0.01 | 0.11 | 0.21 | 0.01 | 0.11 | 0.21 | 0.01 |
| LSD (0.05) Environment pH | | | | | = 0.088 | | | | | | | |
| LSD (0.05)Environment x Amendments pH | | | | | = NS | | | | | | | |
| LSD (0.05) Environment OC | | | | | = 0.164 | | | | | | | |
| Igwelodoha Site | | | | | | | | | | | | |
| PD | 4.9 | 0.98 | 0.08 | 5.0 | 0.99 | 0.10 | 4.9 | 1.15 | 0.08 | 4.8 | 1.04 | 0.07 |
| NPK | 4.8 | 1.11 | 0.08 | 4.9 | 1.04 | 0.10 | 4.9 | 0.72 | 0.08 | 4.8 | 1.02 | 0.06 |
| RHA | 5.2 | 1.23 | 0.09 | 5.0 | 0.77 | 0.07 | 5.0 | 1.19 | 0.08 | 4.8 | 0.98 | 0.06 |
| RH | 4.9 | 1.08 | 0.11 | 5.0 | 1.32 | 0.09 | 4.9 | 1.12 | 0.10 | 4.8 | 1.18 | 0.07 |
| CT | 4.5 | 1.06 | 0.05 | 4.6 | 1.24 | 0.06 | 4.6 | 0.95 | 0.06 | 4.5 | 0.91 | 0.05 |
| Mean | 4.9 | 1.09 | 0.08 | 4.9 | 1.08 | 0.08 | 4.9 | 1.03 | 0.08 | 4.7 | 1.03 | 0.06 |
| LSD (0.05) | 0.08 | NS | 0.01 | 0.08 | NS | 0.01 | 0.08 | NS | 0.11 | 0.08 | NS | 0.11 |

*(a) Effect of 'sawah' field growing environment and soil amendments on the soil CEC, EA and Base saturation (BS) on 0-20 cm topsoil*

The results in Table 4 show that CEC was significantly improved by RHA in most 'sawah' environments. The different soil amendments improved the soil CEC both in Akaeze and Igweledoha. The results also indicate that soil exchangeable acidity decreased significantly in complete 'sawah' environment with the application of amendments. The percent BS was also significantly affected by soil amendments in the 'sawah' environments. The overall drop in the mean EA values in the complete 'sawah' environment was attributed to the 'sawah' system (Nwite *et al.*, 2011).

On the other hand, the results showed an overall trend of significant ($P < 0.001$) increase in CEC and percent BS in 'sawah' system. With the traditional system of rice farming, these soil properties normally decrease during the course of cropping. These results thus further confirm the superiority of the complete 'sawah' system of rice production. Previous experiments conducted near the present sites to evaluate the effect of the 'sawah' system on soil properties similarly showed the 'sawah' system to be superior to improper or non-'sawah' system with respect to generation, release and reserve of soil plant available nutrients (Nwite *et al.*, 2008a, b).
Other studies elsewhere also uphold the superiority of 'sawah' system over non-'sawah' system especially in terms of nutrient reserve for profitable rice production (Wakatsuki *et al.*, 2002; Ganawa *et al.*, 2003; Wakatsuki and Masunaga, 2005).

**Table 4:** Effect of '*sawah*' field growing environment and soil amendments on the soil CEC, EA and Base saturation (BS) on topsoil (0-20cm).

| Amendment | Sawah Environment | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Complete | | | Incomplete | | | Partial | | | Farmers Environ. | | |
| | CEC | EA | BS | CEC | EA | BS | CEC | EA | BS | CEC | EA | BS |
| Akaeze | | | | | | | | | | | | |
| PD | 10.13 | 2.20 | 35.2 | 9.87 | 2.67 | 45.4 | 8.53 | 3.60 | 27.5 | 7.6 | 3.0 | 24.8 |
| NPK | 8.93 | 3.33 | 29.9 | 6.93 | 2.80 | 33.8 | 9.33 | 2.80 | 28.4 | 7.2 | 3.1 | 45.3 |
| RHA | 10.53 | 1.33 | 31.0 | 8.77 | 1.93 | 36.3 | 5.33 | 2.07 | 57.3 | 9.2 | 2.5 | 24.3 |
| RH | 6.67 | 2.87 | 23.3 | 7.07 | 4.53 | 33.6 | 6.13 | 2.47 | 26.9 | 5.5 | 3.1 | 37.9 |
| CT | 5.33 | 3.13 | 18.3 | 3.73 | 4.53 | 23.7 | 4.40 | 4.13 | 19.2 | 3.6 | 4.7 | 17.1 |
| Mean | 8.32 | 2.57 | 27.5 | 7.27 | 3.29 | 34.6 | 6.75 | 3.01 | 31.9 | 6.61 | 3.3 | 29.9 |
| LSD (0.05) | 2.77 | 0.74 | 9.93 | 2.77 | 0.74 | 9.93 | 2.77 | 0.74 | 9.93 | 2.77 | 0.74 | 9.93 |
| Igwelodoha | | | | | | | | | | | | |
| PD | 12.53 | 3.2 | 57.43 | 11.33 | 3.30 | 41.06 | 12.9 | 3.87 | 33.1 | 10.8 | 3.6 | 24.4 |
| NPK | 12.53 | 3.7 | 46.61 | 11.40 | 3.60 | 46.65 | 11.7 | 3.93 | 32.3 | 10.3 | 4.1 | 28.4 |
| RHA | 15.07 | 1.9 | 54.21 | 12.0 | 2.53 | 53.77 | 13.2 | 2.0 | 37.8 | 10.6 | 3.1 | 26.4 |
| RH | 12.67 | 3.3 | 33.71 | 13.20 | 3.60 | 43.43 | 12.8 | 3.53 | 31.9 | 10.9 | 3.7 | 22.1 |
| CT | 6.53 | 4.0 | 19.85 | 4.80 | 4.13 | 22.05 | 8.0 | 4.07 | 16.3 | 5.5 | 5.1 | 16.9 |
| Mean | 11.87 | 3.21 | 41.96 | 10.55 | 3.44 | 41.39 | 11.7 | 3.48 | 30.3 | 9.61 | 3.9 | 23.6 |
| LSD (0.05) | 1.7 | 0.41 | 6.08 | 1.7 | 0.41 | 6.08 | 1.7 | 0.41 | 6.08 | 1.7 | 0.41 | 6.08 |

LSD (0.05) Environment CEC = 1.58
LSD (0.05) Environments BS = 12.31
LSD (0.05) Environments x Amendments BS = 15.22

*(a) Effect of 'sawah' field growing environment and soil amendments on the soil bulk density (BD) and total porosity (TP) on 0-20 cm topsoil*

The bulk density was between 1.11 Mg $m^{-1}$ to 1.46 Mg $m^{-1}$ in the 'sawah' environments at Akaeze site and 1.04 to 1.46 Mg $m^{-1}$ in the 'sawah' environments in Igweledoha site (Table 5). The results indicated that there was a significant difference in the bulk density with amendments in different 'sawah' environments. Also the mean bulk density of soils in the complete 'sawah' environment was significantly lower than the corresponding mean bulk density of other 'sawah' environments. Higher bulk density according to Mbagwu *et al.* (1984) signified compaction and undesirable soil structure that affects roots and plant growth negatively. In all the 'sawah' field environments, rice husk dust reduced the mean bulk density of the soil more. Nnabude and Mbagwu (1999) showed that rice waste, either burnt or fresh could be effective in the improvement of soil properties. The importance of lower bulk density in the soil as portrayed by the 'sawah' managed environments is the improvement of soil aeration, tilt and better water infiltration in addition to unreserved root penetration.

In agreement to these results, Abe *et al.*, (2007) found in two non-puddled inland valleys with fairly equal clay contents in Abakaliki and Bende in South-eastern Nigeria an increase in topsoil BD when compared to puddle area. It has been shown that one of the beneficial agronomic effects of puddling is a reduction in BD (Bhagat *et al.*, 1994; Bajpai and Tripathi 2000). This has also been confirmed by Nwite *et al*, (2008 and 2010) in a research conducted in an inland valley for rice production with 'sawah' system in South-eastern Nigeria. Obalum *et al.*, (2010) also confirmed in their report, that the lowest BD at Ejeti in North-Central Nigeria is a manifestation of the high potential benefit of reduction in BD with the management practice of subjecting the topsoil to puddling in soils with moderate clay contents.

Total porosity also followed a similar trend with soil bulk density (Table 5). While total porosity differed significantly with soil amendments in both locations, it also differed significantly with different 'sawah' field environment. In both locations, total porosity was always significantly higher in complete 'sawah' environment plots than in other 'sawah' managed environments (Table 5). The results here also showed the beneficial contribution of the organic amendments in improving the soil total porosity. Furthermore, complete 'sawah' managed environment could provide management strategies as to the improvement of soils liable to compaction and other negative physical properties when puddle for rice production, (Nwite *et al.*, 2010). The high total porosity was associated with low BD. According to Essoka and Esu (2003), any inland valley with soils that exhibit high TP (of about 55%) and low mean BD (of about $1.0Mgm^{-3}$) would be suitable not only for swamp rice production, but also for dry season farming. In this regard, the suitability of the two locations for 'sawah' rice cultivation and the capability to support other crops especially during the dry season ranges from farmer's field environment through partial field and incomplete 'sawah' field environment to complete 'sawah' field environment.

**Table 5:** Effect of '*sawah*' field growing environment and soil amendments on the soil Bulk density (BD) and Total porosity (TP) on 0-20 cm topsoil

| | *Sawah* Environments | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Complete | | Incomplete | | Partial | | Farmers Envi. | |
| Amendments | (mg m-1) BD | (%) TP | (mg m-1) BD | (%) TP | (mg m-1) BD | (%) TP | (mg m-1) BD | (%) TP |
| Akaeze location | | | | | | | | |
| PD | 1.21 | 54.2 | 1.16 | 56.1 | 1.23 | 53.7 | 1.32 | 50.2 |
| NPK | 1.25 | 52.7 | 1.23 | 53.6 | 1.31 | 50.6 | 1.26 | 52.3 |
| RHA | 1.29 | 51.3 | 1.22 | 53.9 | 1.29 | 51.2 | 1.23 | 53.8 |
| RH | 1.11 | 58.0 | 1.23 | 53.7 | 1.23 | 53.7 | 1.26 | 52.6 |
| CT | 1.37 | 48.2 | 1.39 | 47.9 | 1.38 | 47.8 | 1.46 | 44.8 |
| Mean | 1.25 | 52.8 | 1.25 | 53.0 | 1.29 | 51.4 | 1.31 | 50.7 |
| LSD (0.05) | 0.07 | 2.63 | 0.07 | 2.63 | 0.07 | 2.63 | 0.07 | 2.63 |
| LSD (0.05) Environment x BD = 0.054 | | | | | | | | |
| LSD (0.05) Env ironment x TP = 1.61 | | | | | | | | |
| Igweledoha | | | | | | | | |
| PD | 1.22 | 54.0 | 1.27 | 52.2 | 1.28 | 51.7 | 1.30 | 51.1 |
| NPK | 1.27 | 52.2 | 1.31 | 50.6 | 1.33 | 49.7 | 1.33 | 49.8 |
| RHA | 1.29 | 51.4 | 1.22 | 54.1 | 1.20 | 54.8 | 1.29 | 51.2 |
| RH | 1.07 | 59.8 | 1.23 | 53.5 | 1.04 | 60.9 | 1.32 | 50.2 |
| CT | 1.46 | 45.0 | 1.40 | 47.0 | 1.42 | 46.3 | 1.46 | 45.0 |
| Mean | 1.26 | 52.5 | 1.29 | 51.5 | 1.25 | 52.7 | 1.34 | 49.4 |
| LSD (0.05) | 0.08 | 2.91 | 0.08 | 2.91 | 0.08 | 2.91 | 0.08 | 2.91 |
| LSD (0.05) Environment x BD = 0.08 | | | | | | | | |
| LSD (0.05) Environment x TP = 2.98 | | | | | | | | |

(a) *Effect of 'sawah' field growing environment and soil amendments on the rice grain yield (ton/ha)*

Table 6 shows the effects of different 'sawah' growing environments treated with different amendments on the rice grain yield. The results show that rice grain yield was significantly increased by both 'sawah' managed environments and soil amendments, with complete 'sawah' environment amended with poultry droppings giving the highest at 7.5 tons per hectare which was significant in Igweledoha location, while the highest statistical increase in grain yield was recorded at Akaeze from complete 'sawah' environment treated with RHA. However, it was observed here that the crop responded differently to the soil amendments and growing environments. Consequently, the underlying fact was that, in both locations, more grain yield was obtained in complete 'sawah' growing environment. Ofori *et al.,* (*2005*) and Nwite *et al.,* (2008) reported high grain yield under good water management conditions in 'sawah' with optimum input level. Nwite *et al.,*(2011) further showed that good water management condition prevailing in the proper 'sawah' growing environment might have contributed to the high rice grain yield.

**Table 6:** Effect of '*sawah*' field growing environment and soil amendments on the rice grain yield (t $ha^{-1}$)

| | Sawah Environment | | | |
|---|---|---|---|---|
| Akaeze site | Complete | Incomplete | Partial | Farmers Environ. |
| PD | 4.48 | 5.18 | 4.90 | 3.92 |
| NPK | 5.39 | 4.55 | 4.69 | 3.64 |
| RHA | 5.46 | 4.06 | 4.06 | 4.34 |
| RH | 4.62 | 4.62 | 4.55 | 4.13 |
| CT | 3.29 | 2.94 | 2.94 | 2.00 |
| Mean | 4.65 | 4.27 | 4.23 | 3.61 |
| LSD (0.05) | 0.52 | 0.52 | 0.52 | 0.52 |
| LSD (0.05) Environments grain yield = 0.40 | | | | |
| LSD (0.05) Environments x Amendments grain yield = NS | | | | |
| Igweledoha site | | | | |
| PD | 7.52 | 4.90 | 5.11 | 4.55 |
| NPK | 6.28 | 4.90 | 4.69 | 4.62 |
| RHA | 6.65 | 4.90 | 4.48 | 4.06 |
| RH | 6.37 | 4.90 | 4.62 | 4.76 |
| CT | 3.08 | 2.80 | 3.01 | 2.14 |
| Mean | 5.98 | 4.48 | 4.38 | 4.03 |
| LSD (0.05) | 0.63 | 0.63 | 0.63 | 0.63 |
| LSD (0.05) Environments grain yield = 0.60 | | | | |
| LSD (0.05) Environments x Amendments grain yield = NS | | | | |

## Conclusion

Soils of the studied areas are low in pH and poor in plant nutrients. In spite of this, the 'sawah'-managed system was able to improve pH (slight increases) of the two locations. In addition, 'sawah' growing environments influenced other soil properties in various ways. Based on this, one can conclude that soil pH, OC, TN and other fertility index as well as bulk density and total porosity could be improved using complete 'sawah' technology in inland valleys of South-eastern Nigeria. It was also observed that soil amendments used improved pH, TN, CEC, base saturation and soil total porosity. Rice grain yield was significantly increased by both 'sawah' managed environments and soil amendments.

### References

Abe SS, Oyediran GO, Yamamoto S, Masunaga T, Honna T, and Wakatsuki T.(2007). Soil development and fertility characteristics of inland valleys in the rain forest zone of Nigeria: physicochemical properties and morphological features. Soil Sci. Plant Nutr. 53:141–149

Anderson, J.M and J.S.I. Ingram (1993). Tropical Soil Biology and Fertility: A handbook of Methods. C.A.B. International; 59-62

Andriesse W (1998). Mapping and characterizing inland valley agro-ecosystems: the case of West Africa. In: Wetland characterization and classification for sustainable agricultural development. FAO Corporate Document Repository. Available online: http://www.fao.org/docrep/003/x6611e/x6611e03a.htm#1_MAP

Asadu, C.L.A and F.O.R. Akamigbo, (1990). Relative Contribution of Organic matter and clay fractions location exchange capacity of soils in southern Nigeria. Bamaeu Journal of Agricultural Research, 7: 17-23.

Bajpai RK, and Tripathi RP (2000) Evaluation of non-puddling under shallow water tables and alternative tillage methods on soil and crop parameters in a rice-wheat system in Uttar Pradesh. Soil Tillage Res 55:99–106

Bhagat RM, Sharma PK, and Verma TS (1994) Tillage and residue management effects on soil physical properties and rice yields in north western Himalayan soils. Soil Tillage Res 29:323–334

Blake GR, and Hartge KH (1986) Bulk density. In: Klute A (Ed) Methods of soil analysis, part 1: physical and mineralogical properties (2nd edition). American Society of Agronomy Monograph No. 9. American Society of Agronomy, Madison, pp 363–382

Enwezor, W.O., A.C. Ohiri, E.E. Opuwaribo and E.J. Udoh, (1988). A review of fertilizer use of crops in South-eastern Zone of Nigeria. Fertilizer Procurement and Distribution Department, Lagos.

Essoka AN, and Esu IE (2003) Physical properties of inland valley soils of central Cross River State, Nigeria. Global J Agric Sci. 2(1):37–42.

FAO, (1988). Soil Map of the World: 1:5 million (Revised Legend). World Soil Resources Report, 60. Food and Agricultural Organization (FAO), Rome.

Ganawa, E.S.M., M.A.M. Soom, M.H. Musa, A.R.M. Shariff and A. Wayayok, (2003). Spatial variability of total nitrogen and available phosphorous of large rice field in '*sawah*' Sempadan Malaysia. Sci. Asia, 29: 7-12.

Gee GW and Bauder JW (1986) Particle size analysis. In: Klute A (Ed). Methods of soil analysis, part 1: physical and mineralogical properties. Agronomy Monograph No 9. American Society of Agronomy, Madison, pp 91–100.

Mbagwu J.S.C; R. Lal; and T.W. Scott (1984). Effect of Desurfacing Alfisols and Ultisols in Southern Nigeria. II: Changes in soil physical properties, Soil Science Society of American Journal, vol.48, pp 834 – 838.

McLean, E.O., (1982). Soil pH and lime requirement. In: A.L. Page, R.H. Miller and D.R. Keeny, (Eds.). *Methods of Soil Analysis*, Part 2. Am. Soc. Agron., Madison, pp: 199-224.

Nnabude P.C; and J.S.C. Mbagwu (1999). Soil water relations of a Nigerian Typic Haplustult Amended with fresh and burnt rice-mill wastes. Soil and tillage Research, vol.50, No.3-4, pp207 - 214

Nelson DW, and Sommers LE (1996) Total carbon, total organic carbon, and organic matter. In: Sparks DL (Ed) Methods of soil analysis, part 3: chemical methods. Agronomy Monograph No 9. American Society of Agronomy, Madison, pp 961–1010

Nita, J.C., C.A. Igwe and T. Wakatsuki, (2008a). Evaluation of 'sawah' rice management systems in an inland valley in south-eastern Nigeria I: Soil chemical properties and rice yield. Paddy Water Environ. 6: 299-307.

Nwite, J.C., C.A. Igwe and T. Wakatsuki, (2008b). Rice yield and changes in some soil properties improvement and rice yield in a '*sawah*' rice farming following '*sawah*' in an inland valley in south-eastern Nigeria. Proceedings of Int. Conf. on Sustainable Agriculture for Food, Energy and Industry (ICSA), pp: 988-992, 2-6 July, 2008 at Hokkaido University Conference Hall, Sapporo, Japan

Nwite JC, Igwe CA, and Wakatsuki T (2010) Evaluation of sawah rice management system in an inland valley in south-eastern Nigeria II: changes in soil physical properties. J Water Resource Prot 2:609–618.

Nwite J.C; S.E. Obalum; C.A. Igwe; and T. Wakatsuki (2011). Properties and Potential of Selected Ash Sources for Improving Soil Condition and 'Sawah' Rice Yields in a Degraded Inland Valley in South-eastern Nigeria. World Journal Agricultural Sciences 7(3): 304-310. 2011. ISSN 1817-3047.

Obalum S.I.; J.C. Nwite; J. Oppong; C.A. Igwe and T. Wakatsuki (2010). Comparative topsoil characteristics of 'sawah' rice fields in selected inland valleys around Bida, North-Central Nigeria: Textural, structural and Hydro-physical properties. J. Paddy Water Environ. 2010. DOI 10.1007/s10333-010-0233-3.Published online: 23 October 2010. Springer.

Ofori, J., Y. Hisatomi, A. Kamidouzono, T. Masunaga. and T. Wakatsuki, (2005). Performance of rice cultivars in various 'sawah' ecosystems developed in inland valleys, Ashanti region, Ghana. Soil Sci. Plant Nutr. 51:469 – 476.

Ogobod, E.N. and P.A. Nnabude, (2004). Evaluation of the Performance of three varieties of land rice in degraded acid soil in Abakaliki, EbonyI State. Journal of technology and

Education in Nigeria, 9(2): 1-7.
Rasmussen KJ (1999). Impact of ploughless soil tillage on yield and soil quality: A Scandinavian view. Soil & Tillage Research 53, 3-14.
Rhoades, J.D., (1982). Cation exchange capacity. In: A.L. Page, R.H. Miller and D.R.Keeny, Eds.).*Methods of Soil Analysis*, Part 2. Am. Soc. Agron., Madison, pp: 149-157.
Tebrügge F and Düring RA (1999). Reducing tillage intensity: a review of results from a long-term study in Germany. Soil and Tillage Research, 53, 15-28.
Thomas, G.W., (1982). Exchangeable cations. In: A.L. Page, R.H. Miller and D.R. Keeny, (Eds.), Methods of Soil Analysis, Part 2. Am. Soc. Agron. Monogr. Madison, pp: 159-165.
USDA, (1998). Keys to Soil Taxonomy. Natural Resources Conservation Services, United States Department of Agriculture, Washington, D.C.
Wakatsuki, T., E. Otoo and G.O. Olaniyan, (2002). Restoration of degraded inland watersheds in West Africa: Eco-technology Approach. In: Proceedings of 17th WCSS, 14-21 August 2002, Thailand.

# Rice yield response to variation in soil physico-chemical properties: A case study of the 'Sawah' and rain-fed systems in a lowland ecology in Ghana.

J. Oppong[1] and T. Wakatsuki[2].

[1]*CSIR- Soil Research Institute of Ghana, Kwadaso, Kumasi;* [2]*Kinki University, Faculty of Agriculture, Nara, 631-8505, Japan.*

**Abstract:**

Ghana is a net importer of rice due to low rice yields from its traditional systems of rice cultivation. A study on two different inland valley rice ecologies in the country's forest zone, rain-fed lowland (RLE) and *Sawah*, examined the variations in their soil physical and, chemical properties and how these relate to grain yield. Significant ($p < 0.05$) variations were found between the *Sawah* and the RLE, for all soil parameters studied. The soil physico-chemical parameters that gave highest rice grain yields were those on the *Sawah*. For all the soil properties, rice yields linearly related most to the soils degree of saturation with a coefficient of determination ($r^2$) of 0.84. Positive values of degree of saturation which gave higher rice yields were mainly obtained on *Sawah*. Mean grain yield exceeding 5.0Mg $ha^{-1}$ was only obtained when the degree of saturation is positive throughout the period of rice growth. Under rain-fed conditions, low rice yield was caused by the persistent negative degree of saturation during the growing season. Though the interaction between the suitable physical and chemical properties on *Sawah* gave higher rice yield, the yield declines on *Sawah* soils with C:N ratios higher than 13 and a degree of saturation higher than 4.5%. Further studies on relationship between degrees of saturation, C:N ratio and the current fertilizer recommendation on rice yield are needed.

**Key words:** chemical properties, rain-fed lowland ecology, *Sawah*, soil physical properties.

## Introduction

Rice (*Oryza sativa*) production has seen the fastest rate of increase than any other crop in Ghana over the last decade (MOFA, 2009). Nonetheless, the totality of rice grain obtained from local rice fields only meets about 40 % of the country's rice demand making Ghana a net importer of the commodity (FAO, 2008). The general low production of rice in the country stems from the dominance of rain fed rice ecologies in the rice production system. The rain fed ecologies either suffer from water insufficiency, improper water management or inefficient input utilization.

Over the years, considerable efforts, in terms of bio-technological and eco-technological innovations, have gone into improving rice yield in the country. The bio-technological interventions are improved rice varieties, fertilization, pests and diseases control and management. And the most notable eco-technology has been the irrigated rice ecology. These bio-technologies, have given their optimum performance and the best grain yield under irrigated rice ecology (Ofori et al, 2005).

In Ghana, three dominant rice ecologies namely, the rain fed upland ecology, the rain fed lowland ecology (RLE) and irrigated rice ecology are practiced. In the forest zone of the country, where rice production is mainly inland valley based, the major rice ecologies are the RLE and irrigated lowland rice ecology. The RLE have, over the years, been the dominant traditional practice since it gives a reasonable higher and reliable grain yield than the upland ecology due to the favourable hydrological conditions of the IVs where it is cultivated. The irrigated lowland rice ecology, referred to in this text as 'Sawah', which is a recent introduced technology is cheaper, easier to construct and more profitable to operate by the small scale rice farmer than the earlier introduced large scale centrally managed irrigated system (Hirose and Wakatsuki, 2002).

The preference of Inland valleys (IVs) for both the rain fed lowland ecology and the 'Sawah' is due to their good and durable water resources, flat terrain and fertile soils required for successful cropping of rice (Oosterbaan, et al., 1986; Annan et al, 2002). These characteristics have been found to be basic to most inland valleys. Yet, rice yield on the RLE has mostly been subdued by either too much or insufficient water due to lack of water management with its associated nutrient imbalance and weed infestation. Grain yield from the 'Sawah' has therefore been found to be far higher than this traditional system of rice cultivation (Buri et al, 2007). In West Africa, the variation in soil physical properties on 'Sawah' at different locations have been investigated (Obalum et al, 2010). Similarly, the effect of the chemical properties on Sawah rice yield has also been reported (Issaka et.al, 2009). The interactive effect of the chemical and physical properties on rice yield of 'Sawah' and other dominant rice ecologies in West Africa are hardly known. It is an established fact that land preparation especially wet tillage (puddling) necessary for leveling and transplanting rice in *Sawah* affects soil physical and chemical properties. Puddled soils are known to retain water longer for crop consumption rather than losing it to percolation. (Bhagat et al., 1994), Puddling, however, increases water required for rice cultivation to over 35% higher than in a no-tillage system (Bhushan et al., (2007). With rice yield in Nigeria, puddling has been found not to alter it on soils with relatively high clay content (Lal, 1986). High hydraulic conductivity that leads to percolating from the root zone is anonymously known to cause leaching and loss of nitrogen in the ionic form. Nitrogen is no doubt the most important nutrient for the resource poor rice farmer in terms of crop requirement, rate of application and cost.

It is in this regard that the influence of land preparation for rice cultivation on soil physical and chemical properties in Ghana needs to be investigated. Rain fed lowland ecology and *Sawah* differ in modifications to the topographical and ecological features of the soil on which they are established. *Sawah* is a level basin which ponds and distributes irrigation water by gravitational flow. According to Wakatsuki (1994), *Sawah* is a more suitable term to describe such rice ecology than the term paddy which is interchangeably used for rice grain and the environment in which rice grows. The rain fed lowland ecology is a slash, burn and no-till cultivation method with no modification in the natural topography or hydrology of the inland valley land form. The two rice production systems can therefore be compared on the same taxonomy.

The rain fed lowland ecology is still the most widespread rice production in the forest zone of Ghana, both in acreage and number of farmers since most rice farmers have not adopted the 'sawah' due to lack of power tillers among others problems (Oladele and Wakatsuki, 2009). 'Sawah' construction requires considerable investment that is usually beyond the reach of the resource poor inland valley rice farmer. A concurrent comparison of the soil physical and chemical properties of the two rice ecologies with the aim of improving the rain fed ecology using the 'sawah' as a standard is a necessary step to boost Ghana's rice production level in the short term.

**Materials and Methods**

A three consecutive years' study was conducted at Adugyama (6°53′N 1°52′45″E), Biemso No.1 (6°53′N 1°51′E) and Kwadaso (6°40′30″N, 1°40′30″E) on established 'Sawah' and rain fed lowland rice fields in the years 2007, 2008 and 2009. Rainfall data was collected for each location each year for the period of study with a manual rain gauge. The plots designated as treatments for sampling were: standard 'sawah': (well bunded, well leveled, rice transplanted, plot flooded for most times and drained for fertilizer applications and prior to harvesting only) and standard rain fed lowland: rice seed dibbled after slash and burn with trash removed. Nine plots, per rice ecology per location giving, were sampled in a randomized completely block design (RCBD). The rice fields had cropping history of 3 to 10 years of rice cultivation. The '*Sawah*' and the RLE fields were adjacent to each other in the same river valley. The 'Sawah' was puddled with a two steel-wheeled twelve horse power tractor (power tiller) each year before transplanting of rice. A spacing of 20 cm x 20 cm of plant hills with two stands per hill at transplanting and after thinning (for the dibble stands on the RLE) was adopted. Weeds were controlled with a combination of propanil and 2, 4, D herbicide where necessary. The rice was fertilized at a rate of 60-40-40 NPK per ha. Basal fertilizer (40-40-40 NPK per ha), was applied a week after transplanting and 3 weeks after thinning of the dibbled stands and top dressed with 20 kg N/ha at 8 weeks after the basal fertilizer application. The rice variety used was Jasmine 85. Fifty four random soils samples each were taken from all the three locations for laboratory analysis. Particle analysis (pipette method) was done for textural classification of the soils. Subsequent soil sampling based on an RCBD was done during the period of crop growth and just after harvest to determine the physical and chemical soil parameters.

*Determination of Soil Physical Properties*

The soil physical parameters determined from soil samples were:

(i) *Bulk density ($gcm^3$) and gravimetric moisture content (w)* which were determined with known volume of soil oven dried at $105^0$C to a constant weight. The dry sample was reweighed to determine the moisture content. The bulk density was then calculated from the ratio of the dry weight of the soil and the volume of the soil. The gravimetric moisture content was the difference between the wet weight of the soil and its dry weight. Volumetric moisture content (%) was derived by the multiplying the gravimetric moisture content by the bulk density of the sample.

(ii) *Total Porosity (%) of the sample:* This was derived from the formula {(1-bulk density/2.67) x 100}. Degree of Saturation (%): was calculated from the difference between the volumetric moisture content and the total porosity. The soil was sampled with 5 cm core samplers up to a depth of 20 cm and the mean values of parameters presented are those of 0- 20 cm depths. Few samples were taken up to the depth of 45 cm for which only the bulk densities were determined.

(iii) *Saturated hydraulic conductivity (mm $day^{-1}$):* The steady-state infiltration rate was determined with a double ring infiltrometer for selected 'Sawah' and rain-fed lowland plots after land preparation before planting and the values were converted to saturated hydraulic conductivity (Ks) by multiplying by 1.45.

*Determination of soil chemical properties*

Soil samples for the determination of chemical parameters, taken by auger to a depth of 20 cm were air-dried, ground and passed through a 2 mm sieve. Soil pH was measured in a soil to water ratio of 1:1. Total nitrogen was determined by the Kjeldahl method. Available phosphorus was extracted with Bray No. 1 solution and P was measured on a spectrophotometer. Organic carbon was measured by the method of Nelson and Sommers. Exchangeable bases were extracted with 1.0 M ammonium acetate solution after which the potassium contents in the extract were determined by flame photometry. The rice grain was harvested from a 4 $m^2$ for each plot at 17 week after transplanting and the grain yield converted to Mg $ha^{-1}$.

**Results and Discussion**

Cumulative rainfall values recorded from August to December for 2007, 2008 and 2009 for the locations are Adugyama (593.4 mm, 442.7 mm and 469.6 mm), Biemso No.1 (686.5 mm, 507.2 mm and 525.4 mm) and Kwadaso (786.5 mm, 516.2 mm and 534.0 mm) respectively. Adugyama had the lowest rainfall amounts for the study period.

*Soil texture*

The particle size analysis of the samples from the experiment sites showed that 80% of the soils were of silty loam texture (sand, 18.82 ±7.06, silt, 63.13 ±7.30 and clay, 18.05 ±5.14), and 10 percent each were of loamy texture (sand, 38.50 ±8.05, silt, 46.45 ±1.22 and clay, 15.05 ±8.11) and silty clay loam texture (sand, 17.11 ±0.24, silt, 53.44 ±1.42 and clay, 29.45 ±1.183). The inferences and the conclusions made on this study are based mainly in reference to a silty loam soil texture. Table 1 and 2 give the mean values of chemical and physical properties of the '*Sawah*' and RLE.

*Soil chemical properties*

In general, rain-fed lowland ecologies have relatively acidic soils than 'Sawah' rice fields. The results show that 'Sawah' rice cultivation significantly improves the soil chemical parameters. The significant improvement in the chemical properties of 'sawah' soils may be due to the routine ploughing of the remaining rice debris into the soil as opposed to the burning of the trash that is cleared on the rain fed lowland ecology to facilitate planting.

*Soil physical properties*

Significant differences also exist between 'sawah' and the rain fed lowland ecology and the most notable ones are the degree of saturation and saturated hydraulic conductivity (Ksat.). The high permeability of the rain fed ecology soils allows excessive percolation through their profile and hence the profile remains relatively dry for most periods of rice growth. This high percolation is also likely to increase leaching and loss of nutrients from the root zone of a standing rice crop.

**Table 1:** Mean values of selected soil chemical properties in the study area.

| *Sawah* Location | Year | pH ($H_2O$) | OM (%) | TC (g/kg) | TN (g/kg) | C:N ratio | Av. P ($mgkg^{-1}$) | Ex. K ($cmolkg^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| Adugyana | 2007 | 5.0 | 4.1 | 23.0 | 2.7 | 8.5 | 2.7 | 0.32 |
| | 2008 | 5.2 | 4.0 | 224 | 2.0 | 11.2 | 2.6 | 0.31 |
| | 2009 | 5.9 | 3.9 | 21.8 | 2.3 | 9.5 | 2.4 | 0.32 |
| Biemsd | 2007 | 5.7 | 3.3 | 18.5 | 1.4 | 13.2 | 3.6 | 0.27 |
| | 2008 | 6.0 | 3.5 | 19.6 | 1.6 | 12.3 | 3.5 | 0.25 |
| | 2009 | 5.0 | 3.2 | 17.9 | 1.6 | 11.2 | 3.5 | 0.26 |
| Kwadaso | 2007 | 4.9 | 2.2 | 12.3 | 1.3 | 9.5 | 3.2 | 0.22 |
| | 2008 | 5.6 | 2.4 | 13.4 | 1.3 | 10.3 | 3.2 | 0.22 |
| | 2009 | 5.6 | 2.5 | 14.0 | 1.4 | 10.0 | 3.2 | 0.23 |
| *'Sawah'* Mean | | 5.4 | 3.2 | 18.1 | 1.7 | 10.6 | 3.1 | 0.27 |
| **Rain fed Lowland Ecology** | | | | | | | | |
| Adugyana | 2007 | 4.8 | 1.8 | 10.1 | 1.6 | 6.3 | 9.0 | 0.16 |
| | 2008 | 4.5 | 1.6 | 8.9 | 1.4 | 6.4 | 8.7 | 0.16 |
| | 2009 | 4.2 | 1.2 | 6.7 | 1.2 | 5.6 | 8.7 | 0.17 |
| Biemsd | 2007 | 5.2 | 2.1 | 12.1 | 1.1 | 11.0 | 9.0 | 0.13 |
| | 2008 | 5.0 | 1.7 | 9.5 | 1.2 | 7.9 | 8.8 | 0.14 |
| | 2009 | 4.8 | 1.3 | 7.2 | 1.2 | 6.0 | 8.9 | 0.14 |
| Kwadaso | 2007 | 4.9 | 2.6 | 14.2 | 1.1 | 12.9 | 6.0 | 0.17 |
| | 2008 | 4.4 | 2.0 | 11.2 | 1.1 | 10.2 | 6.1 | 0.17 |
| | 2009 | 4.4 | 2.1 | 11.0 | 0.9 | 12.2 | 6.2 | 0.18 |
| RLE Mean | | 4.7 | 1.8 | 10.1 | 1.2 | 8.4 | 7.9 | 0.16 |
| LSD | | 0.5 | 0.9 | 5.1 | 0.4 | 2.3 | 2.7 | 0.06 |

OM - Organic Matter; TC - Total Carbon; TN – Total Nitrogen

**Table 2:** Mean values of soil physical properties in the study area.

| | Location | Year | Total Porosity % | VMC % | Deg. Sat. % | Bulk Density $gcm^{-3}$ | Ksat. mm $day^{-1}$ |
|---|---|---|---|---|---|---|---|
| *Sawah* | Adugyana | 2007 | 61.7 | 65 | 3.3 | 0.9 | 10.4 |
| | | 2008 | 62.1 | 65.1 | 3.0 | 1.1 | 2.7 |
| | | 2009 | 61 | 64.6 | 3.6 | 1.0 | 3.6 |
| | Biemso 1 | 2007 | 57.8 | 62.7 | 4.9 | 1.0 | 11.3 |
| | | 2008 | 58.1 | 60 | 1.9 | 0.9 | 2.1 |
| | | 2009 | 59 | 63.1 | 4.1 | 1.0 | 4.1 |
| | Kwadaso | 2007 | 56.2 | 58.5 | 2.3 | 1.0 | 13.4 |
| | | 2008 | 57.2 | 58.8 | 1.6 | 1.1 | 1.5 |
| | | 2009 | 57.9 | 59.6 | 1.7 | 1.0 | 1.7 |
| Overall Mean | | | 59.0 | 61.9 | 2.9 | 1.0 | 5.6 |
| Rain fed Lowland Ecology | | | | | | | |
| | Adugyana | 2007 | 40 | 26 | -14.0 | 1.4 | 252.3 |
| | | 2008 | 39.6 | 25.4 | -14.2 | 1.5 | 250.4 |
| | | 2009 | 36.4 | 26 | -10.4 | 1.5 | 248.6 |
| | Biemso 1 | 2007 | 42.1 | 30.1 | -12.0 | 1.5 | 324.0 |
| | | 2008 | 40.1 | 28.3 | -11.8 | 1.6 | 320.0 |
| | | 2009 | 37.6 | 30.5 | -7.1 | 1.5 | 310.6 |
| | Kwadaso | 2007 | 41.3 | 28.2 | -13.1 | 1.4 | 187.2 |
| | | 2008 | 40 | 30.3 | -9.7 | 1.4 | 185.1 |
| | | 2009 | 39.1 | 28.6 | -10.5 | 1.5 | 182.6 |
| Overall Mean | | | **39.6** | **28.2** | **-11.4** | **1.5** | **251.2** |
| LSD | | | 10.1 | 17.5 | 7.5 | 0.3 | 131.5 |

VMC- volumetric moisture content of soil

**Table 3:** Mean values of soil properties and rice yield.

| Soil Property | | Rice Ecology | |
|---|---|---|---|
| Physical | Parameter | *'Sawah'* | RLE |
| | Total Porosity | 59.0 | 39.6 |
| | VWC | 61.9 | 28.2 |
| | Deg. Sat. | 2.9 | -11.4 |
| | Bulk Density | 1.0 | 1.5 |
| | Ksat. | 5.6 | 251.2 |
| Chemical | | | |
| | pH | 5.4 | 4.7 |
| | OM (%) | 3.2 | 1.8 |
| | TC (g $kg^{-1}$) | 18.1 | 10.1 |
| | Total N (g kg-1) | 1.7 | 1.2 |
| | C:N ratio | 10.6 | 8.4 |
| | Av. P (mg $kg^{-1}$) | 3.1 | 7.9 |
| | Ex. K (cmol $kg^{-1}$) | 0.3 | 0.2 |
| Rice Yield (t $ha^{-1}$) | Mean | 6.6 | 2.2 |

*Rice yield relationship with chemical and physical soil properties.*

The high organic matter content, with it associated favorable nutrient content and low compaction and positive degree of saturation due to low permeability of 'sawah' soils promoted favourable rice grain. However, the best linear correlation between the rice yield and soil was obtained with the soil's degree of saturation. The linear relationship between the degree of saturation and rice yield (Figure 1) gave the highest coefficient of determination ($r^2$) of 0.84.

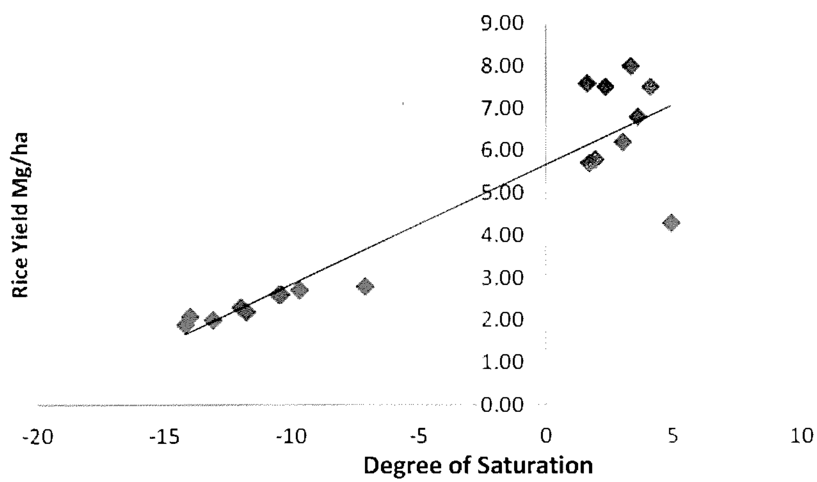



Figure 1: Relationship between soil degree of saturation and rice yield

This relationship shows that rice yield exceeding 5.0 Mg $ha^{-1}$ can only be obtained from rice fields with positive values of degree of saturation.
The very low saturation conductivity of the *Sawah* soil was also associated with soil compaction at the plough sole. The bulk densities of the *Sawah* soils at depths below 30 cm were significantly higher than that of the rain fed lowland soils that are generally more compact in the top horizon (Figure 2).

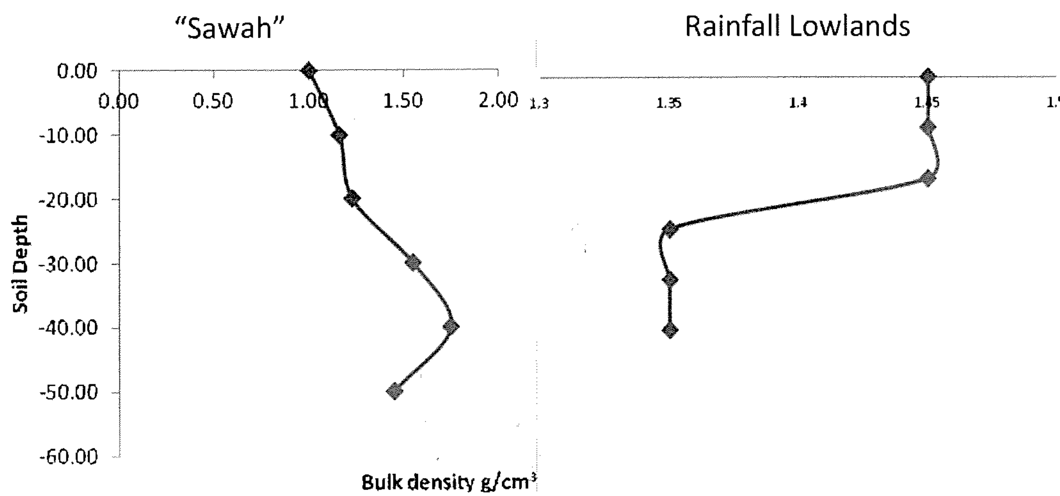



**Figure 2:** Variation in soil bulk density (soil compaction with depth) for the rice ecologies

**Conclusion**

This study has shown difference in soil physical and chemical properties and how they influence rice grain yield on the 'Sawah' and RLE rice fields. The study has also shown that the degree of saturation of the soil is a soil parameter that influence rice yield. Soil physical properties are influenced by *Sawah*. There is the need for research to help introduce some of the 'sawah' qualities into the RLE to help improve the degree of saturation in the short term. This will significantly help to improve their current level of grain yield, which barely exceeds 2.0 Mg $ha^{-1}$ and only enough for subsistence. This increased grain yield will give them more income to invest in the 'sawah' technology. An investigation to also establish the best degree of soil saturation and C:N ratio that will interact to give the optimum yield on 'Sawah' fields is necessary.

## Acknowledgement

The authors are grateful to the Japanese government through the Kinki University for funding the New 'Sawah' Project that sponsored and supported this study.

### References

Annan-Afful E. and Wakatsuki T., 2002. Toposequence as influenced by land use in the inland valley watershed of Ashanti Region, Ghana. Conference paper no. 1146-presented at the 17th World Congress of Soil Science, August Thailand.

Bhagat, R.M., Sharma, P.K., Verma, T.S., 1994. Tillage and residue management effects on soil physical properties and rice yields in north western Himalayan soils. Soil Tillage Res. 29, 323-334.

Buri, M.M., Issaka R.N., Wakatsuki, T., 2007. The 'Sawah' technology of rice production for lowlands: An effective tool for poverty alleviation in Southern Ghana. 4th International Conference of African Soil Science Society. Ghana Institute of Management and Public Administration (GIMPA), 7 – 13 January 2007, Accra, Ghana.

Bhushan L., Jagdish K., Ladha J.K., Gupta R.K., Singh S., Tirol-Padre A., Saharawat Y.S., Gathala M., Pathak H., 2007. Saving of Water and Labour in a Rice–Wheat System with No-Tillage and Direct Seeding Technologies, *Agron. J.* **99** (2007), pp. 1288–1296.

FAO, 2008. Imports of milled rice by country and geographical region. http://www.google.com.FAOSTATDatabase, 2008, FAO, Rome, 22 Sept. 2008.

Hirose, H., and Wakatsuki, T. 2002. Restoration of Inland Valley Ecosystems in West Africa, Norin Tokei Kyokai, Tokyo. pp 572.

Issaka R.N., Buri M.M. and Wakatsuki T., 2009. Effect of soil and water management practices on the growth and yield of rice in the forest agro-ecology of Ghana. Journal of Food, Agriculture & Environment Vol.7 (1) : 214 - 218

Lal, R. 1986. Effects of 6 years of continuous no-349 till or puddling systems on soil properties and rice (*Oryza sativa*) yield of a loamy soil. Soil Tillage Res. 8, pp. 181-200.

Moorman, F.R., and van Breemen N., 1978. Rice: soil, water, land. Los Baños (Philippines): International Rice Research Institute. 185 p.

MOFA., 2009. Agriculture in Ghana. Facts and Figures (2009). Ministry of Food and Agriculture (MOFA), Ghana.

Oosterbaan, R.J., Gunneweg, H.A. and Huizing, A. 1986. Water Control for Rice Cultivation in Small Valleys of West Africa, Published in Annual Report 1986, p 30-49, International Institute for Land Reclamation and Improvement (ILRI), Wageningen, The Netherlands. On website www.waterlog.info

Obalum S. E., Nwite J. C., Oppong J., Igwe C. A., Wakatsuki T., 2010. Comparative topsoil characterization of 'sawah' rice fields in selected inland valleys around Bida, north-central Nigeria: textural, structural and hydro-physical properties. Paddy Water Environ. Springer-Verlag

Ofori J., Hisatomi Y., A Kamidouzono A., Masunaga T., Wakatsuki T., 20005. Performance of Rice Cultivars in Various 'Sawah' Ecosystems Developed in Inland Valleys, Ashanti Region, Ghana. Soil Science and Plant Nutrition: 51 (4), 469-476.

Oladele O. I. Wakatsuki T., 2009. Effect of land tenure on the adoption of 'sawah' rice production technology in Nigeria and Ghana. Journal of Agricultural Science and Technology. Volume 3, Number 10, Serial Number 23.

Wakatsuki T. 1994: Soil, people and sustainable agriculture in tropics: Potential of 'sawah'-based agriculture in tropical Africa. Tropics, 3, 3-I

# Managing the challenges in optimizing wetland management via 'sawah' rice production: Abeokuta experience

[1]Adigbo S.O, [2]Wakatsuki T. and [3]Odedina, J.N.

[1]*Crops Research Programme, Institute of Food Security, Environmental Resource and Agricultural Research, University of Agriculture, Abeokuta, Nigeria;* [2]*School of Agriculture, Kinki University, Nara 631-8505, Japan;* [3]*Department of Plant Physiology and Crop Production, University of Agriculture, Abeokuta, Nigeria. E-mail:* sundayadigbo@yahoo.com

**Abstract**

Most developing countries including Sub-Sahara Africa in general have never been able to produce sufficient food to meeting the teaming population in spite of the abundance of inland valleys which have great potential to be optimized without investment on expensive irrigation systems. Inland valleys show considerable potential for intensification and sustainable land use. The potential impact of this valley is related to the presence of water and total areas covered for the production of many food crops. However, they are only marginally utilized. New 'sawah' rice production technology was established in Abeokuta 2010 and repeated in 2011 as demonstration plot in the University of Agriculture, Abeokuta, Nigeria to showcase the inherent potential and sustainable agricultural practice to the farmers in Ogun State, Nigeria. This paper therefore highlights the natural abundance of the highly productive resources, yield potential, robustness, resilience and sustainable 'sawah' rice based production technology that could be adopted by small scale farmers in Nigeria. It also emphasize the harrowing experiences during natural disaster (such as flood) and the associated problems such as weed infestation, diseases infections, rodents damage, more usage of fertilizer. The role of government policies in stabilizing agricultural produce, such as importation, subsidies and price support as it affects peasant farmers are also discussed. 'Sawah' rice technology has the potential of enhancing sustainability of inland valley if well managed and free from natural disaster.

## Introduction

Tarnocai (1979) defined wetland as lands having the water table at, near, or above the land surface or which is saturated for a long enough period to promote wetland or aquatic processes as indicated by hydric soils, hydrophilic vegetation, and various kinds of biological activity which are adapted to the wet environment. Such flooded areas are generally considered to be more robust and resilient to land use pressure than the fragile uplands (Becker and Diallo, 1992; Gopal *et al.*, 2000; Dixon and Wood, 2003). They are characterized by fine-textured soils (Abergel, 1993), are islands of biodiversity (Gawler, 2002), providers of clean water and air (Dixon, 2002) and potentially highly productive sites for agriculture (Becker and Johnson, 2001; FAO 2003). They are valuable for agriculture and are important to international biodiversity as breeding grounds for migratory birds (World Bank, 2006). Tropical Asia, with about 1/13 of the world's land area, has more than 1/3 of the potentially arable lowlands (FFTC, 2007). This, perhaps, point to the fact why Asia is leading in rice production. Wetlands in Sub-Saharan Africa are estimated to cover 228 million ha (FAO, 1998; Bergkamp, 2000). There is a preponderance of inland valleys in West Africa, where valley bottoms and hydromorphic fringes are estimated to occupy 22-52 million ha of land (Windmeijer and Andriesse, 1993). In rural West Africa, less than 10% of an estimated 55 million ha of wetlands are being used for agriculture (Thenkabail *et al.*, 1995) suggesting that wetlands are grossly underutilized for food crop production as opposed to the Asia continent.

The estimated 3 million ha of the fertile soils of the fadama in Nigeria with residual moisture in the dry-season, offers attractive opportunities for the arable farmers to grow off-season high value crops (World Bank 2001; Adigbo and Adigbo, 2011) but this resource has not been fully exploited. The underutilization of inland valley in Nigeria has also been reported by FAOSTAT, (2008) by indicating that Nigeria, as a nation, has the inland valley resource and management potential to produce enough rice to meet local and as well as for exportation. This under utilization has ironically ranked Nigeria as the second largest importer of rice in the World after Philippine (Africa Rice Center 2008a). However, in West Africa, Nigeria is the leading producer of rice in the sub region (Africa Rice Center (WARDA), 2008b) but the quantity produced is far below consumption. The utilization of inland valley was further improved by increasing the crop intensification from two to three crops per year (Adigbo *et al.*, 2007 Adigbo *et al.*, 2010) without supplemental irrigation as the sustainability and judicious fertilizer utilization were not as efficient in rain-fed system.

Therefore, effective management of inland valleys via friendly ecological technologies such as 'sawah' rice based production system to enhance the sustainability of inland valley could become a laudable option to closing the gap between production and consumption. This paper therefore highlights the yield potential, robustness, resilience and sustainable 'sawah' rice based production technology that could be adopted by small scale farmers in Nigeria. It also emphasizes the harrowing experiences during natural disaster (such as flood) and its associated problems such as weed infestation, diseases infections, rodents damage, more usage of fertilizer.

*Rice Ecologies and their Potentials*

The yield of rice in inland valleys is generally much higher than on the uplands (IITA, 1980; 1988). There is enough residual soil moisture or shallow ground water table for crops other than rice in dry season (Raunet, 1984). The average yields of the world's rice-growing areas are 4.9, 2.3, 1.5 and 1.2 t $ha^{-1}$ for irrigated, rain-fed lowland, flood prone and upland, respectively while the average yield of West Africa's rice-growing area are 5.0, 2.1, 1.3 and 1.0 for irrigated, rain-fed lowland, flood prone and upland, respectively (Anon, 1993). The cost of irrigation equipment is, however, prohibiting for resource-poor farmers to acquire for rice production in Nigeria. Therefore, the rain-fed lowland rice in the available inland valley that gives relatively higher yield of rice as compared to the upland can be taken advantage of, at no extra cost.

Out of the total land area of 1.64million ha devoted to rice cultivation in Nigeria, 1%, 5%, 16%, 30% and 48% is grown to mangrove swamp, deep water rice, irrigated lowland, rain-fed upland and rain-fed lowland, respectively. In West Africa, however, of the total land area of 4.01million ha devoted to cultivation of rice, 1%, 9%, 12%, 44% and 31% is planted to mangrove swamp, deep water, irrigated lowland, rain-fed upland and rain-fed lowlands respectively Lançon and Erenstein (2002). To increase the production of rice in West Africa therefore there is the need to re-allocate more resources to inland valley which are more productive than dissipating our energies and scare resource on the upland. More importantly, the adoption of simple technology such as 'sawah' that will enhance the productivity of inland valleys should also be accepted if the gap between consumption and production must be closed in West Africa. Asia continent is leading in rice production in the world, probably because, they chose the right combination of ecology and technology. The time has come for farmers in Sub-Sahara Africa to relocate rice production in the upland to more productive lowland ecology using the 'sawah' rice production technology.

*Sustainable 'sawah' rice production systems*

The concept and term 'sawah' refers to man-made improved rice growing environment with demarcated, bunded, puddled and leveled rice field with water inlets and outlets for water control in the inland valley which can be springs or pumps (Wakatsuki *et al.*, 2005). The 'Sawah' system of rice production ensures proper management of the rice environment leading to efficient and higher rice grains production with higher returns is a better option to current systems (Wakatsuki, 2005). It is one of the most efficient systems that will ensure adequate production to meet the ever increasing demand and save the country from the use of scare foreign exchange resources for its importation (Buri *et al.*, 2007).

The project is embarking on the process of mass adoption for the whole country with its attendant challenges of procurement of power tillers used in land preparation. The 'sawah' project focuses on three important areas: (i) enhances soil and water management which is important for sustainable rice production; (ii) the package significantly increases rice yield and (iii) the dissemination of the 'Sawah' technology through a participatory learning approach enhances rapid adoption among rice farmer.

It is well-known that weeds can be controlled by means of efficient water control. But it is not well evaluated that the nitrogen fixation by soil microbes under a submerged 'sawah' systems could reach 20 – 100 kg $ha^{-1}$ $year^{-1}$ in Japan and 20 – 200 kg $ha^{-1}$ $year^{-1}$ in the tropics depending on the level of soil fertility and water management (Kyuma 2003, Hirose and Wakatsuki 2002). This amount is comparable to the nitrogen fixed by leguminous plants. Under submerged condition, because of reduction of ferric iron to ferrous iron, phosphorous availability is increased and acid pH is neutralized, hence micro-nutrients availability is also increased (Kyuma, 2003). There are other benefits of 'sawah' systems. The eutrophication mechanisms are not only encouraging the growth of rice plant but also encourage the growth of various algae that increase the nitrogen fixation. The quantitative evaluation of nitrogen fixation in 'sawah' systems including the role of algae will be an important future research topic.

Under nitrate rich submerged water conditions, 'sawah' systems encourage denitrification. Easily decomposable organic matter becomes substrate of various denitrifyers. Purification of the nitrate polluted water is another function of 'sawah' system (Kyuma, 2003).

*Experiences in Abeokuta 'sawah' rice production systems*

'Sawah' field was introduced and established in Abeokuta, Nigeria in 2010 and repeated in 2011 cropping season. The performance of Abeokuta 'sawah' was rated the best in Nigeria by 'sawah' team in 2010 cropping season. However, the story was not palatable because of the damaged caused by flood coupled with non-release of approved fund in 2011 cropping season.

**'Sawah' rice field experience in 2011**

The rainfall pattern in Nigeria in 2011 was an aberration from the normal. The rains did not come when they should and when finally they came; they were torrential coupled with destructive flood. The central drainage canal was washed away or seriously weakened that mending was difficult because of the sandy nature of the soil (loamy sand). So much money and time were invested in managing the damaged caused by the floods. It was difficult mending the canal. Nationwide problems such as poor post harvest facilities, poor marketing structures and the role of government policies in stabilizing agricultural produce, such as importation, subsidies and price support have actually aggravated the situation. Our inability to effectively control water given the sandy nature of the soil resulted in weeds, rodent infestation and higher rate of fertilizer application.

**Problems arising from leakages**

*Weeds*: Failure to supply water to uniformly cover the 'sawah' units, created aerobic situation which allow serious weed infestation. It is well-known that weeds can be controlled using water. This could have been achieved by eliminating air (i.e. inundation of 'sawah' with water) which is one of the conditions for germination (air, water and temperature). However, because water control was inadequate aerobic condition was created giving room for all the conditions necessary for weed seeds to germination. Consequently, weed became serious problems which resulted in weeding 'sawah' field three times as opposed to one weeding in 2010 cropping season without flood.

*Grass cutter:* Normally, when 'sawah' fields are inundated, rodents find water logging condition uncomfortable hence they avoid the field. But because 'sawah' field was dry, the invasion by grasscutters was very apparent and significant in spite of the facts that hunters were invited to prevent this damage.

*More fertilizer usage*: Usually, when the 'sawah' field is well managed with good water control, the benefit derivable from the various N-fixing sources such as bacterial, blue-green algae, geological fertilization and the availability of phosphorus are promoted. Consequently, more fertilizer was used to obtain the minimum grain yield of 4 t $ha^{-1}$ rather than augmenting the various benefits of 'sawah'.

*Lack of funding*

In fairness to 'sawah' team leader, he promptly approved fund for Abeokuta in response to our call for financial help to ameliorate the damaged caused by the flood but the funds were never released. The lack of funds to effectively control water further aggravated the problems of rodent, bird and weed damages. It must be noted that withholding money met for 'sawah' field operation led to debt.

**Poor post harvest facilities and poor marketing structures.**

In the face of these problems, we decided to invest in processing the previously harvested paddy but the quality of the milled rice was not attractable enough to consumers. In order words, the locally milled rice could not stand the competition with the imported polished rice in the market. Arising from poor processing facilities coupled with poor marketing structure, the poor quality milled rice was given out at a giveaway price below market price.

**The role of government policies**

In stabilizing agricultural produce, through importation, subsidies and price support further aggravated issues. The low command price of our last year processed rice could be linked to government policy in the sense that there was virtually no price support for agricultural produce in Nigeria. Heavy importation of rice into Nigeria is a good deterrent to peasant farmer who have the courage to grow rice. The issue of subsidies if it ever existed does not benefit the peasant farmers for whom it was meant. In a way the global problem within the country also affected those of us who dare to produce rice and mill locally. If Nigeria could import one million tonnes of rice, valued at seven hundred million US dollar (US$700m) or about one hundred and six billion naira (N106 billion) from the Peoples Republic of Thailand every year (Sams, 2010), then importation policy would not encourage local production and processing of rice.

**Conclusion**

Naturally abound inland valleys in west Africa are high potential resources, that can support our food sufficiency efforts if well managed as is done in Asia. 'Sawah' technology if well managed and free from natural disaster has the potential to enhance the sustainable use of inland valley compared to rain-fed inland valley or upland ecologies adopted in West Africa. Viable and implementable government policies should be in place to cushion farmers' suffering and encourage them to adopt new technologies. Prompt release of funds and making power tillers available to resource poor farmers is very important for 'sawah' to adoption by farmers.

**References**

Adigbo. S.O., Okeleye, K.A. and Adigbo, V.B. 2007. Performance of upland rice fitted into lowland rice and vegetable/cowpea sequence in inland valley, Agron. J. 99 (2007) 377-383.

Adigbo, S. O., Ojerinde, A. O., Ajayi, O.and Nwilene F. E. 2010. Effects of sowing methods on upland rice in lowland Rice-Vegetable Sequence in Inland Valley Journal of Agricultural Science and Technology. Volume 4, No.3 (Serial No.28)

Adigbo, S.O. and Adigbo, V.B. 2011. Effects of site and insecticide application on growth and grain yield of local and improved cowpea varieties in south-western Nigeria Archives of Agronomy and Soil Science Vol. 57, No. 2, April 2011, 179–191

Africa Rice Centre (WARDA).2008a. Africa Rice Trends 2007. Cotonou, Benin: Africa Rice Centre (WARDA). 84 pp.

Africa Rice Centre (WARDA)/FAO/SAA. 2008b. NERICA: the New Rice for Africa–a Compendium. EA Somado, RG Guei and SO Keya (Eds.) Cotonou, Benin: Africa Rice Centre (WARDA); Rome, Italy: FAO; Tokyo, Japan: Sasakawa Africa Association. 210 pp Anon 1993. Rice Almanac. International Rice Research Institute, Los Banos. Laguna. Philippines; 142pp.

Balek, J. 1983. Hydrology and water resource in tropical regions. Elseivier publ., Amsterdam, pp 123-134

Bergkamp G., Pirot, J.Y.and Hostettler, S. 2000. Integrated Wetlands and Water Resources Management, IUCN, Gland, Switzerland, 2000.

Becker, L. and Diallo, R. (1992) Characterization and classification of rice agro-ecosystems in Côte d'Ivoire. West Africa Rice Development Association, Bouaké, Côte d'Ivoire. 135 pp.

Becker, M. and Johnson, D.E. 2001 Improved water control and crop management effects on lowland rice productivity in West Africa. Nutrient Cycling in Agro-ecosystems 59, 119-127.

Buri, M.M.; Issaka, R.N. and Wakatsuki, T. (2007): The sawah technology of rice production for lowlands: An effective tool for poverty alleviation in Southern Ghana. Paper presented at the 4th international conference of the Africa soil science society organized at the Ghana Institute of Management and Public Administration (GIMPA), Accra, Ghana from 7th-13th January, 2007.

Dixon, A.B. (2002) The hydrological impacts and sustainability of wetland drainage cultivation in Illubator, Ethiopia. Land Degrad. Develop. 13(1), 17-31.

Dixon, A.B. and Wood, A.P. (2003) Wetland cultivation and hydrological management in eastern Africa: Matching community and hydrological needs through sustainable wetland use. Natural Resources Forum 27(2), 117-129.

Food and Agriculture Organization (FAO). 1998. Wetland Characterization and Classification for Sustainable Agricultural Development, FAO Regional Office for Africa, Rome, FAO SAFR, ISBN 0-7974-1928-4, 1998. Available online at: http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/003/X6611E/x6611e03.htm

Food and Agriculture Organization of the United Nations (FAO) (2003) World Soil Resources. http://www.fao.org/ag/agl/agll/wrb/wrbmaps/htm/soilres.htm.

FAO (2004) Fact sheet No 5 on International Year of Rice www.rice2004.org

Food & Fertilizer Technology Centre (FFTC) 2007. Ecological sustainability of the paddy soil-rice system in Asia, Available online at: http://www.agnet.org/library, 2007

Gawler, M. (2002) Strategies for wise use of wetlands. Best practices in participatory management. International IUCN, WWF Publication No. 56, Wageningen, The Netherlands.

Gopal, B., Junk, W.J. and Davis, J.A. (2000) Biodiversity in wetlands: Assessment function and conservation. Volume 1. Blackhuys Publishers, Leiden, The Netherlands. 353 pp. International Institute of Tropical Agriculture (IITA). 1980. Consolidated report of UNDP/FAO/IITA Sierra Leone rice project. International Institute of Tropical Agriculture, Ibadan, Nigeria. pp 18-20

IITA, 1988. International Institute of Tropical Agriculture's strategy plan 1989-2000. IITA, Ibadan, Nigeria. pp 85-86

Kyuma K. 2003: Paddy Soil Science, 305 pp., Kyoto University Press Lançon, F and Erenstein, O. 2002. Potential and prospects for rice production in West Africa. Paper presented at the Sub-Regional Workshop on harmonization policies and Co-coordinating programs on rice in ECOWAS Sub-Region Accra, Ghana 25-28 February, 2002

Raunet, M.1984. Les potentialiles agicoles des bas-fonds en region inter tropicales: l' example de la cultire du ble de contre-saison a Madagasca. Agronomic Tropicale. 39:121-135.Sams, N. 2010. Nigeria spends N106b to import rice from Thailand.

http://234next.com/csp/cms/sites/Next/Money/Business/5519234-147/story.csp

Tarnocai, C. 1979. Canadian Wetland Registry. In: Proceedings of a workshop on Canadian wetlands environment. C.D.A. Rubec and F.C. Pollett (Eds) Canadian Land Directorate, Ecological Classification Series No 12, pp 9-38.

Thenkabail, S. Prasad, S. Nolte, C. 1995. Mapping and characterizing inland valley agro-ecosystems of West and Central Africa: A methodology integrating remote sensing, global positioning system, and ground truth data in a geographic information systems framework, RCMD Monograph, No. 16, IITA, Ibadan, Nigeria, 1995.

Wakatsuki, T.; Otoo, E.and Olaniyan O.G. (2002). Restoration of degraded inland watersheds in West Africa: eco-technology approach. In: Proceeding of 17th WCSS, 14-21 August 2002, Thailand, 12021-12028

Wakatsuki, T.; Buri M.M. and Fashola, O.O. 2005 Ecological engineering for sustainable rice production and the restoration of degraded watersheds in West Africa. In: Proceedings of rice research conference, IRRI, pp 336-366

Windmeijer, P.N and Andriesse, W. (Eds), 1993. Inland valleys in West Africa. An agro-ecological characterization of rice growing environments. Publication 52. International Institute for land Reclamation and Improvement, Wageningen, The Netherlands, 160 pp.

World Bank, 2001. Second Fadama Development Project (SFDP), Livestock Compont. http://www.usaid.gov/ng/downloads/markets/fadamalivestock.doc

World Bank, 2006. Press Release, Nigeria Receives Aid to Manage At-Risk Water Ecosystems, Accessed on the 8th December, 2006. Available online at: http://usinfo.state.gov.

## How to Succeed in 'Sawah' Eco-Technology Transfer: Experiences of Bida, Zaria-Nakala UN Villages, FCT-WAKO and Kebbi State, Nigeria

Joshua Aliyu and Baba Taitus

**Abstract**

Agriculture extension is neither a one try and succeed process nor one short and kill effort. This is so because it deals with people, land, relief and other natural phenomenon. And as we look closely to all these, they cannot be manoeuvred easily. It therefore has to take some time before things get fine grained into the desired points. This is why in all Agricultural Extension activities, regular visits and trainings are brought into play as they constitutes paramount structures for bringing about success. Other issues that are of good back up for success of work implementation are determination, interest, knowledge, prowess in message dispensation amongst others. Technical staff therefore need to be well equipped for 'Sawah' to succeed.

### Introduction:

Nigeria no doubt has vast rice growing areas, amongst which are appreciable lands, suitable for rice cultivation in Bida (Niger State) and Zaria (Kaduna State-UNDP Millennium Villages) and Brinin Kebbi (Kebbi State). With this in mind, we have a great task in improving our rice status from the low production point of view. The only way this can be done is through the adoption of improved production technologies such as the 'Sawah' system of rice farming. We indeed have begun with this system and have achieved some level of success. Right now, we have penetrated into some fourteen (14) villages in Bida found in the Middle belt of Nigeria. In Zaria (UNDP Millennium Villages) we have surfaced in three villages, while in Kebbi state we have demonstrated in four towns. These successes have come on board because of the vital roles played by researchers, extensionists and farmers. In all the places where we have demonstrated, personal practice had begun and farmers have totally depended on this technology.

### Derived processes and procedures

(a) *Ways Considered as Parameters for Achieving Sawah Development.*

We have enumerated ways in which we operated and belief that they have assisted immensely in the 'Sawah' Exposition in Bida, Zaria and Kebbi State as already proscribed earlier. To achieve meaningfully results, there must be rules and guidelines to follow. Without seriously considering some of the issues stated below it would be very difficult to record successes.

(i). *Extension must make regular visits and training.*

Indeed regular visits and trainings play major roles in *Sawah* development. This very important practice helps to capture farmers' interest. They view it as something that should be done with a purpose because of the time, finance, and energy put into it. As for training, please avoid training activities which are not practically oriented. Try to demonstrate what you say on the field with the farmers. Farmers often times prefer to work with technical staff that love field work. Avoid giving instructions and telling a farmer to do after you have left because in most cases the operations may not be done at all or done badly.

(ii). *Extension must have good knowledge of sawah.*

*Sawah* we know is a package. It consists of so many things that need to be done right from site selection up to harvesting. Hence a good knowledge of the processes is an adequate tool for work. Good knowledge leads to excellent impartation of such knowledge to the farmers. Inadequate knowledge can lead to distortions that can cause failures or make ones message inarticulate. To succeed we therefore must have a sound knowledge about *Sawah* development

(iii). *Must have extension expertise to relay message.*

The regular visits can be good, coupled with good knowledge about *Sawah* rice farming, but if there is not enough energy to relay such information for farmers to understand, it may not create interest in the farmer to stick to *Sawah*. It is therefore proper to learn the art of relaying information to farmers, so that they can easily understand and get convinced to accept appropriate actions. Hence there is need to have verbal coherent ability for message delivery.

(iv). *Clarify work division issues before commencement of work.*

When a farmer indicates his interest in *Sawah*, we need to iron out issues before any commencement of work. This program, no doubt, is of a farmer participatory approach. In terms of roles to be played, each has functions to perform. These functions need to be well clarified before work starts. We must not allow work to be progress or about to end, before we begin talk of vital things that needed to be discussed at the beginning. This can cause friction, or retard progress of work. An example could be on transplanting. If a farmer is not aware of doing the work from start to finish of this activity, he/she may think that it is the duty of the project or extension officer.

*(v). Solve farmers problems*

It is certain that problems will emanate. When problems crop up in the field in terms of pests, disease or machinery, try to assist in solving them immediately. Delays or not showing much concern is not good. Other problems may come up which may not be associated with '*Sawah*'. Farmers see you as their welfare officer. Try to assist them even though it may not be direct. Help by getting them to people, places where they could get assistance but remember not to make promises that you cannot fulfil.

*(vi). Maintain cordial relationship with farmer.*

A good cordial relationship with farmers is also a very important factor for '*Sawah*' development implementation. Farmers may not develop good understanding and interest for 'Sawah', if working relationship is sagged. Excessive quarrels and dabbling into village issues should be avoided. Note that your major task in these villages is to extend 'Sawah' technology. Pay homage to the village head or community leader intermittently. When you have problems or need any assistance, let them know.

*(vii). Never quit when your first attempt fails.*

If in your first operation, you are not able to get good result, don't quit as quitting is dangerous. Always observe critically to know the reasons for failure and surely you will get reasons. Make your reasons known to the farmer in a way he would understand, and encourage him to make another try. When farmers get to know the causes of some problems, they easily understand and don't get discouraged. However, when no reasons are identified to show for some poor results, farmers may find it difficult to continue. Concentrate on areas where farmers need advice. During field observations, always hammer on areas where farmers need advise for corrections or amendments.

*(viii). Never hide results of rice yields*

Results from 'Sawah' fields are always encouraging. At the end of harvest, transfer information to other villages, particularly to communities where *sawah* has not yet reached. Encourage farmers to visit 'Sawah' fields on their own and when coincidentally we meet them in the field, we should explain to them on how we have arrived at that standard. Use correct tools and materials to ease work on the field.

**(b). Problems Encountered and Solutions**

'Sawah' development is not without problems. Problems can be from extension staff, farmers or the natural environment. Problems that we do observe are location Specific. Hence they are treated under the various locations.

*BIDA (Niger State)*:

*Problems* encountered include: (i) Lack of interest, (ii) fear of Government taking over land, (iii) capital and (iv) land degradation.

*Solutions* provided included education. Lack of interest by some farmers was common at the inception of the programme. However, through education this is not very common now. From time to time farmers are educated on the effect of *Sawah* as a food producing venture which has positive advantage on the totality of their livelihood. Nevertheless, we don't tie ourselves to them permanently trying to encourage them. We move ahead to see those who can take the technology for us to work with because when we make progress, those who showed no interest would get to hear and would follow suit. Through this the percentage of farmers who show no interest is reduced drastically. At the inception of *Sawah*, fear gripped most farmers because they taught of it as a plan by Government to take over their rice fields. Indeed, we had to talk intensively and extensively with ward, village, community heads as well as farmers that their thinking was wrong and that the information was not true. However since then, no single farmer's field had been taken from him/her. Farmers thought that unless you had much capital 'Sawah' was not easy to develop. What we thought them was to redeem small portions of their fields to '*Sawah*' annually, so that they will not have to spend much money at a time. This solved the problem of capital. Within periods their whole field were developed into '*Sawah*'. Hence a farmer can put his whole farm into 'Sawah' within a given time frame.

Land developed into *Sawah* fields becomes degraded. Another problem we encountered was farmer's perception that if a power tiller puddles a field, the result will be erosion leading to degradation of land. We take such farmers to most fields where '*Sawah*' has been in practice and when they fail to see any degraded lands due to 'Sawah'activity, they immediately become convinced.

ZARIA - Kaduna State (UNDP Millennium Villages)

*Problem* encountered was crop yield failures in 2007 and 2008, when rice variety Wita 4 (Faro 52) a long duration variety was used.

*Solution:*

It was realized that this place is in northern Nigeria that witness short rainfall and that the rice variety used could not be grown because of its duration. While in 2007, the crop had very good vegetative growth but unable to mature due to water shortage with a total failure, in 2008, 20% loss was observed. The solution provided was to introduce a short duration hybrid variety-Faro 44 (CP). Since 2009 harvest has been good. The yield for 2011 has been the best so far.

KEBBI State (North West Nigeria)
Problems encountered were (i) improper management of farmer-groups operations and (ii) unmastery skills in power tiller handling.

*Solution* provided was basically training. Time was set aside and farmers trained on how to manage groups. Farmers are therefore becoming perfected. The 'Sawah' demonstration just got to this place this year (2011). Therefore it is expected that operators will have to work for sometime during the coming year (2012) before they can attain some level of perfection.

**Work Scope and Success**
Indeed work scope in terms of site coverage as mention earlier can be put at 25 - 30 villages and towns. On area coverage it can be put at 100 ha. On yield, we have recorded yields not by extrapulation but physical pa%y production of 4.27t $ha^{-1}$, 5.67t $ha^{-1}$ and 7.27t $ha^{-1}$ respectively across locations.

**Comments on Farmers.**
Farmers love to associate with something that could increase their crop yields for the betterment of their livelihood, and this should be the 'Sawah' Technology. Farmers are not difficult in accepting technologies as they are normally perceived. Unclear messages can scare farmers. Farmers now see the sawah system as simple, unchaic, and practicable. My recommendation is that extension should be more upright in the approach to farmers. Farmers are our best friends and so we need to avoid doing things that will put extension on a collision course with them.

**Conclusion**
We have tried to put our experiences into this report hoping that even if some were left out it will not be much. Since a '*Sawah*' operational guide booklet will be published, I have tried to avoid listing all the '*Sawah*' operations. On success, extension has already gotten off to some appreciable footing. I therefore see no reason why we cannot cover effectively the areas intended to be covered in the nearest future in Nigerian.

# Potential Impact of the 'Sawah' System on Rice Production in Ghana.

R. N. Issaka[1], M. M. Buri[1] and T. Wakatsuki[2]

[1]*CSIR-Soil Research Institute, Academy Post Office. Kwadaso-Kumasi. Ghana*
[2]*Faculty of Agriculture, Kinki University, Nara 631-8505. Japan*
*Email:* rolandissaka@yahoo.com

**Abstract**

The 'sawah' system of rice production ensures increase and sustainable rice production, thus increasing income and reducing poverty. To estimate the impact of 'sawah' on rice production in Ghana four scenarios were considered: (i) Business-as-usually: Under this scenario no effective policy put in place and normal practices of rice production maintained. Yield per unit area will remain at 2.4 $MTHa^{-1}$, (ii) There is some amount of commitment. MOFA's target of 3.5 $MTHa^{-1}$by 2015 is achieved, (iii) Serious commitment by all stakeholders with 50% of area under rice production developed into 'sawah' in 2015 and paddy yield averaged at 5.0 $MTHa^{-1}$ under 'sawah' and (iv) Serious commitment by all stakeholders with 75% of area under rice production developed into 'sawah' by 2017 and paddy yield averaged 5.0 $MTHa^{-1}$under 'sawah'. Estimated rice production under 'sawah' in 2015 (scenario 3) will be 54% more than what would have been produced under normal practices (scenario 1). In 2017 if 75% of the land under rice cultivation is developed into 'sawah' then production will be twice what would have been produced under scenario 1. With increasing local rice production the quantity of imported rice will decrease resulting in reduction in pressure on the country's foreign exchange. Promoting the 'sawah' system of rice production will enhance the output and income of the small holder farmers, processors and traders, thus promoting national economic growth and thus enhancing and ensuring food security.

**Key words:** Inland valleys, paddy yield, projections, scenarios,

## Introduction

In Ghana about 13.3 million hectares is potentially arable land(MoFA, 2010), and the density of population per cultivable area is moderate. Nearly 60% of the arable land is presently not cultivated. Although much of this surplus cultivable land may be under temporary bush fallow in the crop rotation/bush fallow system, there still is substantial land which remains fallow every year. The potential area for small scale irrigated 'Sawah' in valleys is estimated at 700,000 hectares (JICA/CSIR-CRI, 2000; Wakatsuki, 1994). There is also the potential for increasing production by increasing productivity. Yields of most crops can be increased significantly through application of improved technologies such as timely and proper application of fertilizers, adequate weeding, use of improved seeds, proper cultural practices, and use of the 'Sawah' system of rice production in the inland valleys.

Critical attention should be given to food production since agriculture is very essential to the macro-economic performance and to the Governments economic recovery and poverty reduction program. Introduction of the 'Sawah' technology (bunded, puddled and levelled rice field with irrigation and drainage facilities) has resulted in significant rice yield. Buri, et al. (2008) observed a significant increase in rice yield (averaged 1.0t $ha^{-1}$ initially and 4.0 t $ha^{-1}$after a year and presently above 5.0 t $ha^{-1}$) when 'sawah' was introduced to farmers in part of Ashanti region. Issaka et al (2009) also observed high rice yield (> 6.0 t $ha^{-1}$) under 'sawah' system over the traditional system. The "sawah' system of rice production satisfies both areas of sound environment and high rice yields. It also enhances nutrient build-up, especially carbon and exchangeable cations. This paper discusses the potential impact of 'sawah' system on rice production in Ghana.

## Materials and Methods

Secondary data were obtained from literature. These include; Estimation of area suitable for *Sawah* development in Ghana (JICA/CSIR-CRI, 2000; Wakatsuki, 1994) and Information on area under rice production and amount produced from 2002 to 2009 (MOFA, 2010). Rice yield per unit area under Sawah system (Buri, et al. 2008, Issaka et al 2009). National average yield of rice was compared to yields under the Sawah system in the development of various scenarios.

## Results and Discussion

*Rice production and productivity*:

National rice production from 2002 to 2009 is presented in Table 1. During this period rice yield per unit area ranged between 1.0-1.5 MT $ha^{-1}$. This very low rice yield suggests the unavailability of good technologies. Under such a situation production can only be improve by increasing the land area under rice production leading to further environmental degradation due to extensive cultivation. Presently rice yield per unit area has increased to 2.4 MT$ha^{-1}$ (MOFA, 2010). This value is still very low if the country is to produce enough rice for consumption and reduce importation. Under the Ministry of Food and Agriculture strategic plan, productivity is targeted at 3.5 MT$ha^{-1}$in 2015 (MoFA, 2010) which still falls below expectations considering the rate of rice consumption in the country.

Table 1. Rice production in Ghana from 2002 to 2009

| Year | Area Cultivated | Paddy Produced '000 MT | Yield $MTha^{-1}$ |
|---|---|---|---|
| 2002 | 123 | 168 | 1.4 |
| 2003 | 118 | 143 | 1.2 |
| 2004 | 119 | 145 | 1.2 |
| 2005 | 120 | 142 | 1.2 |
| 2006 | 125 | 150 | 1.2 |
| 2007 | 109 | 111 | 1.0 |
| 2008 | 133 | 181 | 1.4 |
| 2009 | 162 | 235 | 1.5 |

Adapted from MOFA, 2010.

*Traditional rice production:* In Ghana inland valleys occur throughout the country and have a huge potential for rice production (JICA/CSIR-CRI, 2000). Many inland valleys are annually used largely for rice production and to some extend vegetables. Rice is normally grown using traditional methods.

Lack of structures to manage water, use of a mixture of rice varieties and little or no application of fertilizers. The traditional system of rice production is becoming more unreliable under the current climatic conditions. Crop failure can be as high as 80-100 % when a long drought sets in. To arrest this situation ecological sound management practices need to be adopted

*'Sawah' system of rice production:* 'Sawah' is defined as bunded, puddled and levelled rice field with inlets for both irrigation and drainage. "Sawah" has an intrinsic resistance to erosion and self enriching in some major nutrients. Many studies on the use of 'Sawah' for rice production in Ghana have been done. This range from description of various 'Sawah' systems (JICA/CSIR-CRI, 2000), rice agronomy ( Buri et al, 2004, Issaka, et al. 2009), nutrient status of inland valleys ( Buri et al. 2009, Senayah et al, 2008, Issaka et al 1997) and general development of inland valleys into 'Sawah' fields. Currently rice yield under the 'sawah' system of rice production ranged from 4.0 - 7.5 $MTha^{-1}$. If this condition is up-scaled nationwide rice production will increased significantly.

**Scenarios and Projections**

To increase rice production significantly to the point of self sufficiency requires a systematic and scientific approach. Huge investments using the appropriate technologies are necessary to achieve the desired results. We create scenarios and project rice production under these conditions. Assuming the area under rice cultivation (162,000 ha) in 2009 is maintained in 2015, the production levels will differ depending on the commitment by the Ghana Government towards rice production as follows:

**Scenario One**. Business-as-usual: Under this scenario no effective policy is in place and the normal practices maintained. Yield per unit area will remain at < 2.4 $MTha^{-1}$

*Equation 1.* Production = A x Qn where A is area under cultivation in hectares and Qn is yield per ha under normal practice.

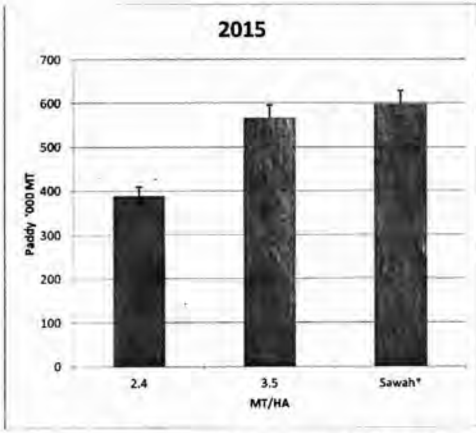
**Scenario Two**. There is some amount of commitment and MOFA's target of 3.5 $MTha^{-1}$ by 2015 is achieved.

*Equation 2.* Production = A x Qt where A is area under cultivation in hectares and Qt is yield per ha (MOFA target)

**Scenario Three**. Serious commitment by all stakeholders with 50% of area under rice production developed into 'sawah' in 2015 and paddy yield averaged at 5.0 $MTha^{-1}$ under 'sawah' while 50% of the area will give 2.4 $MTha^{-1}$.

*Equation 3.* Production = (A/2) x Qn + (A/2) x Qs where A is area under cultivation in hectares and Qs is yield per ha under 'sawah'

Using these scenarios, rice production in 2015 will be below 400,000 MT under scenario one while production will increase significantly under scenario two and three (Fig 1). Paddy produced under scenario three will be at least 200,000 MT more than under scenario one. However rice produced under scenarios two and three will be similar.



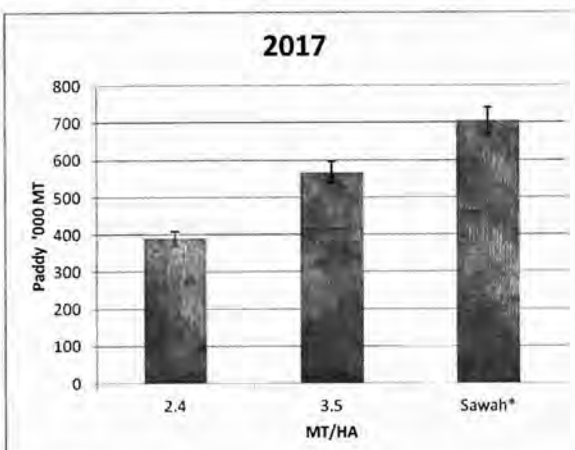

**50% of area under sawah (average yield: 5.0 $MTHa^{-1}$)*

**Figure1.** Projected rice production in 2015 under different scenarios

Scenarios one and two still applicable in 2017, more valleys will be progressively developed into 'sawah'.

**Scenario Four**. Serious commitment by all stakeholders with 75% of area punder rice production developed into 'sawah' and paddy yield averaged 5.0 $MTha^{-1}$ under 'sawah'.

*Equation 4.* Production = (A/4) x Qn + (3/4A) x Qs where A is area under cultivation in hectares and Qs is yield per Ha under 'sawah'




*75% of area under sawah (average yield: 5.0 $MTHa^{-1}$)*

**Figure 2.** Projected rice production in 2017 under different scenarios

## Conclusion

Progressive development of valleys into 'sawah' will ensure significant increases in rice production. By 2017 rice produced under scenario three will be almost twice that produced under scenario one and significantly more than that produced under scenario two. Within the rice value chain small holder males dominate in the production sector while small scale processors and traders are mostly females. Promoting the 'sawah' system of rice production will enhance the output and income of the small holder farmers, processors and traders, thus promoting national economic growth. Additionally the 'sawah' system satisfies both areas of sound environment and high rice yields.

### References

Agriculture in Ghana (2010). Facts and Figures. Ministry of Food and Agriculture (MoFA). Statistics, Research and Information Directorate (SRID). April 2010. Accra

Buri, M. M., Iassaka, R. N., Fujii, H. and Wakatsuki, T. (2009). Comparison of Soil Nutrient status of some Rice growing Environments in the major Agro-ecological zones of Ghana. International Journal of Food, Agriculture & Environment - JFAE. Accepted 26/5/2009

Buri, M.M., Issaka, R.N. and Wakatsuki, T.(2008). Reducing rural poverty through improved and sustainable rice production technologies: A case study of the "sawah" system in the Ahafo Ano South District in Ghana. The International Conference on Sustainable Agriculture for Food, Energy and Industry, July 2nd-6th. Sapporo, Hokkaido, Japan.

Issaka, R. N., Buri, M. M.. and Wakatsuki, T. (2009. Effect of soil and water management practices on the growth and yield of rice in the forest agro-ecology of Ghana. Journal of Food, Agriculture & Environment Vol.7 (1):214-218.

Issaka, R.N., Buri, M.M. and Wakastuki, T. (2001). Evaluation of four rice environments for sustainable rice production. Proceedings of International Workshop on Integrated Watershed Management of Inland Valley-Ecotechnology Approach. Accra, February 6th-8th, Ghana.

Issaka, R. N., Ishida, M., Kubota, D. and Wakatsuki, T. (1997): Geographical Distribution of Soil Fertility Parameters of West Africa Inland Valleys. Geoderma 75: 99-116.

JICA/CSIR-CRI, (2000). Summary Report. Kumasi. Ghana. Senayah J. K., Issaka R. N. and Dedzoe, C. D.(2008). Characteristics of Major Lowland Rice-growing Soils in the Guinea Savanna Voltaian Basin of Ghana. Agriculture and Food Science Journal of Ghana. Vol. 6. P 445-458

Issaka, R. N., Buri, M. M. and Wakatsuki, T. (2009). Effect of soil and water management practices on the growth and yield of rice in the forest agro-ecology of Ghana. Journal of Food, Agriculture & Environment Vol.7 (1):214-218.

Wakatsuki, T. (1994). Global Environmental and Agricultural Production in West Africa. In Rice Culture in West Africa. A Manual for Technical Cooperation- Japan Assistant Development and Extension Association.

# Experiences of 'Sawah' Development Activities in Ondo and Delta States of Nigeria.

Agboola A.O[1], Olanrewaju, J.S[1], Dada-Joel, O.T.[2], Aliyu J[1], Ademiluyi Y.S.[2] and T. Wakatsuki[3].

[1]*New 'Sawah' Project, NCAM, Ilorin, Nigeria;* [2]*National Centre for Agricultural Mechanization, (NCAM), P.M.B 1525, Ilorin, Nigeria;* [3]*Department of Ecological Engineering, Faculty of Agriculture, Kinki University, Nara, Japan. E-mail:* n_agboola@yahoo.com,

**Abstract**

The consumption of rice had risen astronomically in Nigeria and SSA over the last 2 decades. Production of rice to meet demand of the growing population is a major challenge for all stakeholders. The solution to this challenge lies in the realization of rice green revolution through the adoption of "Sawah" Eco-technology. Rice production through site specific adaptation, environmental eco-technology and lowland reclamation is very necessary. "*Sawah*" is an eco-technology concept which improves rice ecology. The term "Sawah" refers to levelled rice field surrounded by bunds with inlets and outlets connecting irrigation and drainage canals. The basic concepts of "*Sawah*" eco-technology are site selection, "*Sawah*" systems design, field development, use of High Yielding Varieties (HYV) of rice, agronomic management involving water management, soil fertility management, weed control and pest management. This paper discusses four important skills and technologies for 'sawah' dissemination as experienced in Ondo and Delta States of Nigeria viz: (1) site selection and site specific 'Sawah' system design,(2) skills for cost effective 'sawah' systems development and management (3) farmers organization for successful on-the-job training, development and management of 'sawah' system, (4) 'sawah'- based rice faming to realize at least the sustainable paddy yield of > 4 $tha^{-1}$ paddy and 20 ton paddy production within three years using one power tiller for 5ha *Sawah* operations.

**Keywords:** dissemination, eco-technology, experiences, farmers, "Sawah"

## Introduction

The consumption of rice had risen astronomically in Nigeria and SSA over the last two decades. Production of rice to meet the demand of the growing population is a major concern for all stakeholders in the rice value chain. The answer led in realizing the target for green revolution in the rice value chain through the adoption of 'Sawah' Eco-technology for rice production on site specific adaptation, environmental eco-technology and lowland reclamation. The realization of Nigerian Rice Green Revolution is not only based on irrigation for water supply, fertilizer for nutrient supply and high yielding varieties but also on managing irrigation for effective water supply. It has been postulated that the prerequisite for a speedy achievement of rice green revolution in Nigeria and Sub-Saharan Africa is through the adoption of the "Sawah" Eco-technology, ( Waktsuki, et al 2009).

Ondo State, is located in the South-western Zone of Nigeria and lies between longitudes 4"30" and 6" East of the Greenwich Meridian, 5" 45" and 8" 15" North of the Equator. Ondo State is composed of lowlands and rugged hills with granitic outcrops in several places. The geo-morphological units of the creek and river rine areas include sand ridges, lagoons, swamp flats, creeks and the anatomising distributaries of the western Niger Delta. Numerous rivers flowing southwards to the Atlantic Ocean drain the state.

The major rivers flow through sedimentary rocks in deeply incised valleys aligned in a north-south direction, into the coastal lagoons. The climate of Ondo State is of the Lowland Tropical Rain Forest type, with distinct wet and dry seasons. The mean annual total rainfall exceeds 2000 millimetres. The natural vegetation is high forest. Over most of the state, the natural vegetation has been very much degraded as a result of human activities, the major being the rotation of bush fallow system.

**Soil:** The soils, derived from Basement complex rocks are mostly well drained, with medium textures. The soils, classified as Ondo Association, are of high agricultural value for both tree and arable crops. The swamp flats are characterised by swampy organic and flooded organic soils.

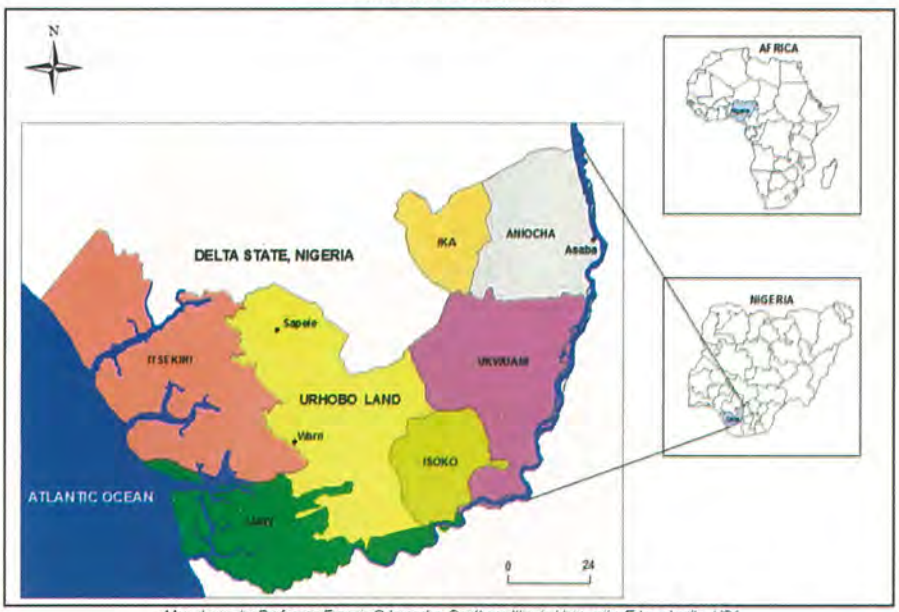

**Fig. 1:** Map of Ondo State of Nigeria

## DELTA STATE

Delta state on the other hand covers a landmass of about 18,050 Km2 of which more than 60% is arable land. The State lies approximately between Longitude 5°00 and 6°.45' East and Latitude 5°00 and 6°.30' North. Delta State is generally low-lying without remarkable hills with a wide coastal belt inter-lace with rivulets and streams, which form part of the Niger-Delta. It lies between the flood plain and Benin lowlands. The swamps are more restricted to broad drainage channels created when this area was an active delta. The average monthly rainfall is about 266.5mm in the coastal areas and 190.5mm in the extreme north. Rainfall is heaviest in July. The vegetation varies from the mangrove swamp along the coast, to the evergreen forest in the middle, and the savannah in the north east.

**Soil:** There are three types of soil in Delta State. These consist of alluvial soil on the marine deposits along the coast; alluvial and hydromorphic soils on marine and lacustrine deposits found in the area closest to the Niger and Benin rivers; and the ferral soils on loose sandy sediments in the dry land areas of the north and northeast. The ferral soils are usually yellowish in colour.

A Map of Delta State, Nigeria, Showing Urhoboland and Other Ethnic Nationalities




Map drawn by Professor Francis Odemerho, Southern Illinois University, Edwardsville, USA



**Fig. 2:** Map of Delta State of Nigeria

## "Sawah" Technology in the States

Ondo and Delta states of Nigeria are among the rice producing states in the country favoured by their ecological and relief pattern. Ondo has about 40,000 hectares of land while Delta has about 20,000 hectares of agricultural land suitable for rice production, (Longtau, 2003). The major rice systems in the two states are shallow fadama and valley bottoms (swamps) due to the soil formation and relief pattern of the states. Valley bottoms, or 'deep *fadama*', provide the ideal environment for rice production. However, due to lack of flood control technology and appropriate varieties, this system remains largely untapped, (Madu-West, 2002).

These prevailing conditions and the multi-functionality of the "Sawah" system makes the two states the target of the Kinki University 'Sawah' Project and NCAM-Kinki University/Fadama III 'Sawah' Technology project.

## Materials and Methods

'Sawah' was introduced to Ondo state in 2008 through the joint efforts of State Agricultural Development Program (ADP) under the auspices of the state commissioner for Agriculture and the sawah project led by Prof. T. Wakatsuki of the Kinki University, Japan. It commenced with demonstration sites covering two hectares at Ahule in the neighbourhood of the state capital.

The 'Sawah' activities in Delta state is as a result of the collaboration between NCAM-Kinki University and Fadama III project of Nigeria. About 2.5 hectares of land was developed in the introductory stage as one of the selected pilot stations was established in ogbologboma/Asaba the South-South geo-political zone of Nigeria.

## Results and Discussion

### Experiences in Sawah Eco-Technology dissemination in the States

*(a) On-the-Job Training of Extension Officers of ADP and Fadama III*

The 'Sawah' activity in the states has led to the training of more than three Officers of Fadama III project in Delta state and five ADP extension officers in Ondo state. The trainings were conducted both on the site and in other locations across Nigeria through collaboration with the International Co-operation Centre for Agricultural Education of Nagoya University, Japan, National Cereal Research Institute, Badeggi, Nigeria and National Centre for Agricultural Mechanization, (NCAM), Ilorin, Niger.a as well as Kinki University, Nara, Japan. The trainings covered different skills of 'Sawah' development techniques which include:

*Site Selection: 2-4days per potential site*

The priority sites were rice cultivation areas for easy dissemination of the Sawah Technology: The best season for the site selection is December/October during the rainfall season, but in the case of Ondo state just before harvesting in November and after harvesting between January/ end of February. This was possible after hearing from rice farmers about the local hydrological conditions of the area which is very important as it helps to identify extreme draught and flood conditions of the area. Characteristics of selected sites should include the following:

a. Secure continuous water flow: Aule in Ondo State had > 5 month base water discharge : > 20lt/sec, i.e. > 1500-2000m$^3$/day, potential irrigated sawah area > 10-20ha.

b. The Flood depth is < 50cm and continuation of the flood is stronger within few days after continuous rainfall. This normally happens in September and with such cases we normally involve big scale engineering works in preparation against the coming flood attack to control water.

c. Flat and very gentle slope :< 2%, slope is < 0-1%, leveling operation is easy.

d. Strong will of rice farmers to master Sawah technology skill and Sawah development by farmers self support effort.

e. Good road access for demonstration

f. Land tenure to secure rent between 5-10 years.

g. Good soil texture (not gravelly)

**Sawah-based rice farming in the first year of New Sawah Development at Aule in Ondo State**

'Sawah' water control: 35 days-work per ha.
'Sawah' system maintenance: 30 work-day per ha.
Transplanting: 15 work-days per ha.
Fertilizer: 2 work-days per ha.
Weeding: 6 work-days per ha.
Bird scaring: 35 work -days per ha.
Harvesting: 10 work-days per ha.
Threshing: 8 work-days per ha.
'Sawah'-based rice faming is to realize at least the sustainable paddy yield > 4t ha$^{-1}$

and 20 ton paddy production within three years using one power tiller for 5ha 'Sawah' Development operations.

### On-the-Job Training of Leading Rice Farmers

During the training as outlined earlier, farmer groups were identified and new ones formed to introduce and disseminate 'Sawah' eco-technology to them. Leading rice farmers were identified and trained in line with the peculiar characteristics of the groups.

### Impact of Activities on Farmers and Society

The impacts of 'Sawah' activities in the states are: (i) Increased youth participation in farming and provision of employment, (ii) De-nitrification of nitrate polluted water, (iii) Watershed agro-forestry (SATOYAMA) adotion which encourages conservation of the environment, forest generation, enrichment of the lowland through various geological processes, (iv) 'Sawah' has contributed to control of flooding and soil erosion in the states (v) 'Sawah' has created cultural landscape and social collaboration among different tribes in both states, (vi) 'Sawah' has become valuable in the current rehabilitation process in the Niger Delta of Nigeria, and (vii) 'Sawah' systems serve as field laboratorys for research and technology generation and the factory for dissemination of the technology developed.

### Challenges

The major challenge facing the dissemination of the 'Sawah' eco-technology in the states is the mechanization of field activities. It has been brought to our notice that mechanizing field operations can easily result in 80% utilizations of the lowlands. Thus, suitable means of adaptation of the power tiller for bund making, canal construction digging, transplanting, harvesting and transportation are required. The following are some of the major constraints experienced during introductory aspects of lowland mechanization for rice production in both Ondo and Delta states:

(i) Scarcity of trained and experienced operators of single axle tractors. Success of several operators depends on expertise level of Power Tiller operator.

(ii) Poor ecology. The lowlands are often with low weight bearing capacity resulting in sinking of heavy single axle tractors in excess of 10hp.

(iii) Inappropriate wheel design: Paddle wheels are better suited for the puddling operation in 'Sawah' lowland basins. Pneumatic tyres or skid wheels are not appropriate and tend to increase the incidence of sinking.

(iv) Limitation in application of Power Tiller to several vital operations of new 'Sawah' development. Bund making takes a significant proportion of power requirement in new sawah development, and there is challenge in finding appropriate adaption of the single axle tractor for this operation. A team of 'Sawah' researchers of the National Centre for Agricultural Mechanization, Ilorin is trying to develop a bund builder implement to be attached to the single axle tractor for this important operation.

(v) Leveling necessitate heavy, medium or light movement of soil mass as determined by topography and layout design of 'Sawah' basins. Efforts at machine adaptation for effective leveling are still being limited by:

a. *Fragmentation or small basin sizes:* the need to preserve the top layer soil where high gradient necessitate more than moderate soil movement. So far, the only practicable option is manual intervention in temporary removal of top soil and replacement after sub-layers has been moved.

b. *Machine sinking* following repetitive passes on 'Sawah' basins in the attempt to achieve leveling is a common feature. To reduce or avoid this, it is important to match the weight of machinery to bearing capacity of the soil, avoid too many post puddling passes and maintain adequate basin water level during leveling.

c. *Maneuverability:* - Since bunds are sources of obstruction to machinery movement in a 'Sawah' basin care must be taken to avoid getting the chassis caught in the heap. Experience has shown that diagonal orientation is preferred in crossing the bunds.

*(vi)* Puddling: - Puddling operation can be hampered by presence of stumps and rock particles in the basin which can damage the cultivator. Attempting a puddling operation without adequately flooding the basin to > 5cm water depth often result in poor performance of the power tiller and eventual sinking whereas heavy soils like clayey hold down the wheels and cultivator of the power tiller.

(vii) Transplanting:- Poor alignment of plant rows due to non-strict compliance with the guidance of the planting ropes create difficulty in mechanized weeding when needed.

(viii) Weeding:- The push-pull rotary weeder is most suitable for control of obnoxious weeds in a flooded sawah basin but this weeder is yet to be popular in our rice growing communities. Presently, hand picking remains the most widely applied option for weed control in a flooded sawah basin.

(ix) Harvesting and Processing: - Non availability of mechanized harvester suitable for the various traditional rice growing terrains has been a constraint to rapid expansion of production with increasing adoption of technologies like 'Sawah'. It has become necessary to mechanize harvesting and processing even at low levels. With the advent of small scale harvesters like "RICH" presently undergoing modification to adapt it to realities of the fields and processing plants capable of presenting rice free of stones and other impurities, there is high hope that locally produced rice can be presented to the market competitively enough to sustain and stimulate further cost effective local production.

## Meeting SERIF'S Target

Continuous study and research into mechanization challenges at several and various stages of 'Sawah' development will help to bring about the much needed realization of rapid rice yield increase and probable realization of the green revolution. To meet the target for 'Sawah' Eco-technology and Rice Farming (SERIF) in Ghana, Nigeria and Sub-Sahara Africa with particular reference to Ondo and Delta States of Nigeria, there is need for more research activities on mechanization, address challenges and find solutions to constraints. Also more people (farmers and Extension agents) have to be empowered through capacity building (training) programs and workshops.

## References

Longtau, T.B. 2003. Relief map of Nigeria.

Wakatsuki T., Buri M.M and Oladele O.I. 2009. West Africa Rice Green Revolution by 'Sawah' Eco-technology and the creation of African satoyama system. Kyoto, Japan

# Impact of Mechanization on Lowland Use and Rice Production in Nigeria

Dada-Joel O.T[1], Faleye T[1], James D[1], Olanrewaju J.S[3], Onyemize U.C[1], Adebija B.A[1], Fagbenja M.A[1], Ademiluyi Y. S[1] and Wakatsuki T[2]

[1]*National Centre for Agricultural Mechanization (NCAM). P.M.B. 1525, Ilorin, Kwara State, Nigeria;* [2]*Faculty of Agriculture, Kinki University, Nara 29201, Japan;* [3]*New 'Sawah' Project, NCAM, Ilorin, Kwara state, Nigeria.* E-mail:temidada@yahoo.com,

**Abstract**

The Nigerian food situation is vulnerable to the changing global trends as the country is a net importer of major food items. The market demand and prices of rice worldwide will likely remain high as other crops, (e.g. maize and cassava) are diverted for bio-fuel production. These global changing trends therefore challenge Nigeria to quickly address this vulnerability by refocusing and retuning the entire agricultural system in the country. There is great potential for Nigeria to achieve large-scale production of rice but this has to be complemented with capacity for high quality post-harvest technologies for processing, storage and marketing to serve both domestic and foreign markets. This study examined the impact of using power tiller as a means of increasing lowland use and mechanizing lowland rice production in Nigeria. The study was carried out in Bida area, Niger state, where the 'sawah' rice farming eco-technological concept was disseminated by Watershed Initiative in Nigeria (WIN) and in Ajase Ipo and Elerinjare of Kwara State. Some of the parameters assessed during the study included average speed of operation, average wheel slip/travel reduction, average draught of implement, and fuel consumption. The cost of operation and yield over five years of usage at Niger State and two years in Kwara State were determined and it was therefore concluded that the power tiller is the most appropriate field machinery for tillage operations such as ploughing, puddling and levelling on lowlands for rice production in Nigeria.

**Key words**: lowland use, mechanization, rice production, power tiller.

## Introduction

Major changes have taken place recently in farming practices in Nigeria. These have been encouraged by the development of irrigation facilities, the adoption of modern high yielding varieties and the proper use of chemicals. Land preparation has also shifted from traditional to mechanized methods. The main reasons are timeliness of operation, better quality of land preparation and weed control, less drudgery and lower tillage costs. Agricultural mechanization is the application of mechanical technology and increased power to agriculture, largely as a means to enhance the productivity of human labor and often to achieve results well beyond the capacity of human labour at minimal cost. This includes the use of tractors of various types as well as animal-powered and human-powered implements and tools, internal combustion engines, electric motors, solar power and other forms of energy.

Mechanization also includes irrigation systems, food processing and related technologies and equipment. Levels and types of improved mechanical technologies need to be appropriate, compatible with local, agronomic, socio-economic, environmental and industrial conditions. Rice has become an important strategic and daily staple food crop in Nigeria. The potential land area for rice production in Nigeria is between 4.6 - 4.9 million ha. Out of this, only about 1.7 million ha (35%) of the available land area is presently cropped to rice (WARDA, 1988).

The main production ecologies for rice in Nigeria are rain-fed lowlands; rain- fed upland, irrigated lowland, deep water / floating and mangrove. Of these, rain-fed lowland rice has the largest share of the rice area (50%) and rice production as shown in Table 1. New high-yielding lowland varieties of the NERICAS are undergoing agronomic evaluation in Nigeria and several other countries.

Small-scale farmers with farm holdings of less than 1 ha cultivate most of the rice produced in Nigeria. However, rice productivity and production at the farm level are constrained by several factors. These constraints include insufficient appropriate technologies, biotic factors, poor supply of inputs, ineffective farmer organizations and groups, low yield and poor milling quality of local rice varieties, poor marketing arrangements, inconsistent agricultural input and rice trade policies, poor extension systems and environmental constraints. These environmental constraints include poor drainage and iron toxicity in undeveloped lowland swamps, poor maintenance of developed lowland swamps, drought, deficiencies of N and P, insufficient rainfall and poor soil management practices. The size of the average family holding in many developing countries is of the order 2 to 5 hectares, with 3 hectares as an appropriate average figure. Such a holding would therefore require a power input of 1.2 kW (Crosceley, 1978). It is therefore the opinion of many that due to the economic level of majority of farmers in developing countries like Nigeria, in transforming from the presently predominant hand- tool technology to a full blown large scale engine power technology, there has to be an appropriate intermediate technology. In the past this has been viewed as the animal draft technology. However, the introduction of two-wheel tractors (power-tillers) in many countries is proving to be a better and more appropriate intermediate technology. In the past five to six years, there has been an influx of two- wheel tractors into Nigeria and the demand has particularly been increasing in rain-fed lowland areas where its use for the cultivation of lowland rice is increasingly becoming popular.

The objectives of this study are to (i) determine the profitability of using power tiller in rice production, (ii) determine the impact of power tiller on increasing lowland use capacity and (iii) determine the impact of using the power tiller as a means of mechanizing rice production.

**Methodology**

*Description of the machine used:* The power-tiller or walking tractor, as it is sometimes called is a single-axle (two-wheel) tractor. This particular one is of Indian make and the model is VST-SHAKTI 130 DI with 10 kW (13 hp) rated power, diesel engine of 2400 rpm rated crankshaft speed. The engine is single cylinder horizontal 4 strokes, water cooled and hand-cranking type. The driving wheels are of two types: the pneumatic type for normal traction and the steel or cage wheel for wet puddling.

*Field layout, location and operations:* The operation of the machine was carried out in wet puddling on two different rice field located at Shaba-Maliki and Ejeti village near Bida on a clayey loamy and sandy soil respectively. Bida is 137 m above sea level and lies on longitude 6° 01'E and latitude 9° 06'N in Niger State of Nigeria. Ajase Ipo of Kwara State is at an altitude of 370 m above sea level and lies on longitude $2^0$ 30'E and latitude $7^0$ 45'N both under the Guinea savannah ecology of Nigeria. The 600 mm tine cultivator was attached to the power tiller and it was used for puddling of the field before transplanting of rice was done. Fashola *et al., (2007)* has a detailed description of the 'sawah' system on farmers' fields. Some of the parameters assessed during the field test included average speed of operation, average wheel slip/travel reduction, average draught of implement and fuel consumption. The soil properties monitored included soil moisture content, bulk density, porosity, penetrometer resistance/cone index and shear strength. The core technique was used in obtaining samples for bulk density measurement, soil penetrometer and shear vane readings were determine *in situ*. Soil samples were obtained at various depths of 7 cm intervals. Soil laboratory analysis was done using standard procedures (Hunt, 1977).

*Cost determination:* Cost calculations for mechanized farm operations are almost similar everywhere. Usually there are basic assumptions and few other adjustments are made to suit the particular needs and locality. For example, while in some countries taxes are paid on agricultural machines and implements, in Nigeria they are tax-free.

Costing of mechanized operation can be done either on an hourly basis or a hectare basis. The former is only meaningful when accurate records of the time (machine hours) are available. In Nigeria, 34.7% of the operator's time was spent in doing unproductive work of which 31.2% represents avoidable delays (Aboaba, 1965). It would be unfair and inaccurate to add this idling time to the overall time for carrying out an operation. The farmer is more interested in knowing how much it will cost him to farm a unit area so as to compare it with the yield per unit area.

Generally, machinery costs fits into two broad categories:
*Fix costs*: The factors involved in the calculation of operating costs of farm machinery can be grouped under two main components - "fixed and variable" costs. Fixed cost includes cost that must always be taken into account whether the machinery is in operation or not. They are related to machine ownership and represent a form of financial discipline, to make sure that the business does in-fact pay-off capital investment within a reasonable period. They are depreciation (on tractor and on implement), interest on investment, taxes, insurance and shelter. After reviewing several methods of cost claculations, it was found that for the Nigerian condition, the straight line method was most appropriate. The equation used was: Depreciation = Initial cost of machine/expected total hours of use.

*Variable costs:* Variable cost is the remaining operating cost that depends on particular operations and is directly proportional to the machinery usage. This includes labour (operator and mechanic), spares, fuel and lubricants.
(i) Labour: The usual daily rate for skilled workers like operators and mechanics increases from N500 in 2002 to N700 in 2006 per day while it was N 1,000 to N 1,200 per day in 2009 to 2010, but it is very uncommon to employ mechanics on a daily wage basis; instead they are paid whenever their services are needed in a case of sudden breakdown.
(ii) Fuel: The variables that have direct influence on the fuel consumption for any operation are speed of operation and soil properties (texture and moisture) and skill

of operator. Fuel cost perper ha can be given as

$$F = \frac{fxp}{c} \quad \ldots\ldots (1)$$

Where F = fuel cost/hectare (ha), f = fuel consumption rate (l/h), p = cost of fuel (l), c = rate performance of machine or machine capacity (ha/l).

The operating cost of power tiller was determined based on its annual use for a period of five years. The cost per year was calculated by the relation:

$$C = \frac{(FC)P}{100} + \frac{H(R\&M)}{10^4} + L + O + F \quad \ldots\ldots\ldots\ldots(2)$$

Where C = annual cost, FC = annual fixed cost, % (interest + taxes + depreciation); this value is often rounded off at 16%, P = purchase price, H = hours used per year, R&M= repair and maintenance cost, % per 100 hr of use, L= labour cost per year, O = oil cost (often 10% of fuel) per year and F = fuel cost per year.

Table 1: Share of rain-fed/irrigated lowland rice areas in Nigeria

| Production system | Major states covered | Share of rice area (%) | Average yield (t $ha^{-1}$) | Share of production (%) |
|---|---|---|---|---|
| Rain-fed lowland | Akwa Ibom, Bayelsa, Edo Benue, Cross River, Ekiti, Ebonyi, Delta, Ogun, Ondo, Kaduna, Lagos Niger and Rivers states. | 50 | 2.2 | 53 |
| Irrigated | Anambra, Benue, Borno. Cross River, Ebonyi, Enugu, Kano, Kebbi, Kogi, Niger and Sokoto states. | 16 | 3.5 | 27 |

*Source*: WARDA (1988)

## Results and Discussions

The summary of the field tests, effects of the tillage tool on some soil physical properties and the operating cost of power tiller are presented in Tables 2-5 The test of significance difference between the measured parameters across sites as presented in Table 3 were not significant for most of the parameters except for Slippage, which was significantly higher in Ajase Ipo with a mean value of about 11.10% when compared to the mean values of Shaba Maliki and Ejeti (10.53% each). For the non significant parameters, however, it was observed that the effect of tillage operations is relatively the same for the three sites. This simply implies that fuel consumption, for instance, did not differ significantly across sites. This was true for all non-significant parameters and conforms to derivation of basic design of small tractors (Crosceley, 1978).

**Table 2:** Descriptive statistics of field operation result

| Parameters | Site | N | Mean | S.D | S.E |
|---|---|---|---|---|---|
| Slippage | Ejeti | 3 | 10.53 | 0.000 | 0.000 |
| | Shaba Maliki | 3 | 10.53 | 0.000 | 0.000 |
| | Ajase Ipo | 3 | 11.10 | 0.000 | 0.000 |
| | Total | 9 | 10.72 | 0.285 | 0.095 |
| Effective field cap. | Ejeti | 3 | 0.047 | 0.008 | 0.005 |
| | Shaba Maliki | 3 | 0.089 | 0.046 | 0.027 |
| | Ajase Ipo | 3 | 0.055 | 0.012 | 0.007 |
| | Total | 9 | 0.064 | 0.031 | 0.010 |
| Theoretical field cap. | Ejeti | 3 | 0.050 | 0.010 | 0.005 |
| | Shaba Maliki | 3 | 0.096 | 0.049 | 0.028 |
| | Ajase Ipo | 3 | 0.071 | 0.009 | 0.005 |
| | Total | 9 | 0.072 | 0.032 | 0.011 |
| Field efficiency | Ejeti | 3 | 93.37 | 1.165 | 0.672 |
| | Shaba Maliki | 3 | 91.96 | 1.526 | 0.881 |
| | Ajase Ipo | 3 | 91.26 | 0.807 | 0.466 |
| | Total | 9 | 92.20 | 1.397 | 0.466 |
| Fuel cons.(l $ha^{-1}$) | Ejeti | 3 | 11.19 | 1.977 | 1.141 |
| | Shaba Maliki | 3 | 12.91 | .812 | 0.469 |
| | Ajase Ipo | 3 | 10.55 | 6.277 | 3.624 |
| | Total | 9 | 11.55 | 3.480 | 1.160 |
| Fuel cons. (l $hr^{-1}$) | Ejeti | 3 | 0.54 | 0.189 | 0.109 |
| | Shaba Maliki | 3 | 1.12 | 0.505 | 0.292 |
| | Ajase Ipo | 3 | 0.54 | 0.189 | 0.109 |
| | Total | 9 | 0.73 | 0.409 | 0.136 |
| Area of land (ha) | Ejeti | 3 | 0.03 | 0.005 | 0.003 |
| | Shaba Maliki | 3 | 0.03 | 0.007 | 0.004 |
| | Ajase Ipo | 3 | 0.04 | 0.005 | 0.003 |
| | Total | 9 | 0.03 | 0.006 | 0.002 |
| Average time of operation | Ejeti | 3 | 21.70 | 3.765 | 2.174 |
| | Shaba Maliki | 3 | 13.15 | 5.541 | 3.199 |
| | Ajase Ipo | 3 | 18.70 | 4.532 | 2.616 |
| | Total | 9 | 17.85 | 5.520 | 1.840 |

SD represents standard deveiation; SE represents standard error

**Table 3.0:** Test of Main Factor Effect (ANOVA)

| | | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Slippage | Between Groups | 0.650 | 2 | 0.325 | 65535. | 0.001*. |
| | Within Groups | 0.000 | 6 | | | |
| | Total | 0.650 | 8 | | | |
| Effective field cap. | Between Groups | 0.003 | 2 | 0.001 | 1.888 | .231 ns |
| | Within Groups | 0.005 | 6 | 0.001 | | |
| | Total | 0.008 | 8 | | | |
| Theoretical field cap. | Between Groups | 0.003 | 2 | 0.002 | 1.862 | .235 ns |
| | Within Groups | 0.005 | 6 | 0.001 | | |
| | Total | 0.008 | 8 | | | |
| Field efficiency | Between Groups | 6.935 | 2 | 3.467 | 2.398 | .172 ns |
| | Within Groups | 8.676 | 6 | 1.446 | | |
| | Total | 15.610 | 8 | | | |
| Fuel cons.(l/ha) | Between Groups | 8.945 | 2 | 4.472 | 0.305 | .748 ns |
| | Within Groups | 87.945 | 6 | 14.657 | | |
| | Total | 96.889 | 8 | | | |
| Fuel cons.(l/hr) | Between Groups | 0.684 | 2 | .342 | 3.137 | .117 ns |
| | Within Groups | 0.654 | 6 | .109 | | |
| | Total | 1.339 | 8 | | | |
| Area of land (ha) | Between Groups | 0.000 | 2 | .000 | 1.232 | .356 ns |
| | Within Groups | 0.000 | 6 | .000 | | |
| | Total | 0.000 | 8 | | | |
| Average time of operation | Between Groups | 112.905 | 2 | 56.452 | 2.589 | .155 ns |
| | Within Groups | 130.830 | 6 | 21.805 | | |
| | Total | 243.735 | 8 | | | |

*significant at 1% level, ns = not significant

Table 4 presents a summary of the soil physical properties considered during the experiment. It was observed that moisture content recorded higher mean values after operation than before operation, while cone index was as much as eighty times larger before operation than after operation. Moisture content and porosity decreased as soil depth increased from 0-7cm to 14 -21cm. Bulk density and cone index increased as soil depth increased from 0-7cm to 14 -21cm. This indicates a positive condition for the flow of water and air through the soil profile and minimum resistance to root growth and proliferation. Puddling with the power tiller has improved soil moisture content, reduced shear strength and penetration resistance as earlier observed by Fashola et al, (2007b).

**Table 4:** Effect of tillage tool on some soil physical properties

| Parameter | Activities | N | Mean | S.D | S. E |
|---|---|---|---|---|---|
| Moisture content | Before operation | 3 | 23.64 | 9.467 | 5.466 |
| | After operation | 3 | 29.51 | 10.070 | 5.814 |
| | Total | 6 | 26.58 | 9.313 | 3.802 |
| Bulk density | Before operation | 3 | 1.57 | 0.279 | 0.161 |
| | After operation | 3 | 1.52 | 0.155 | 0.090 |
| | Total | 6 | 1.54 | 0.204 | 0.083 |
| Cone index | Before operation | 3 | 51.68 | 36.458 | 21.049 |
| | After operation | 3 | 6.20 | 7.946 | 4.588 |
| | Total | 6 | 28.94 | 34.313 | 14.008 |
| Shear strength | Before operation | 3 | 0.032 | 0.024 | 0.014 |
| | After operation | 3 | 0.005 | 0.005 | 0.003 |
| | Total | 6 | 0.019 | 0.022 | 0.009 |
| Porosity | Before operation | 3 | 40.77 | 10.540 | 6.085 |
| | After operation | 3 | 42.67 | 5.859 | 3.382 |
| | Total | 6 | 41.72 | 7.697 | 3.142 |

SD represents standard deveiation; SE represents standard error

The operating cost of power tiller (Table 5) was determined based on the annual usage and farm size. It was evident that the operating cost per annum increased yearly till 2005 based on 4 hours per day usage. For the first five years of operation in Niger State, the highest area of coverage was recorded in 2005. The same year recorded highest cost of repairs and maintenance and paddy yield of 5.2 t ha$^{-1}$. The first three years recorded same volume for repair and maintenance cost until the break down that occurred in 2005. The price of diesel varied between ₦45 per litre to ₦90 per litre between 2002 and 2006. This also contributed to increase cost of production yearly. Nontheless comparing income based on hiring services, there was short fall in 2002. This might be due to the inexperienced nature of the operator in handling the machine. He could not make maximum use of the machine to cover much area. For example in 2002, 80 hrs of operation covered 5 hectare while twice that area was covered in 2003 in 120 hrs, saving 40 hrs. After 2003 there was a gradual increase in revenue generation as the hiring rate increased slightly with other factors of production. Since the machine was not hired to farmers, but rather given to them freely so that they can be familiar with it and considering the yield at Ajase Ipo within the first two years of power tiller introduction it is hoped that there will be a tremendous increase in subsequent years with proper field management.

**Table 5:** Annual use of power tiller

| Year | Total annual use (hr) | Total annual coverage (ha) | R&M cost per annum (000 ₦) | Fuel cost per annum (₦) | Total operational per annum (000 ₦) | Hiring cost per annum (000 ₦) | Yield (t/ha) |
|---|---|---|---|---|---|---|---|
| 2002 + | 80 | 5 | 10 | 2, 722 | 27.55 | 15 | 5.0 |
| 2003 + | 120 | 10 | 10 | 6, 050 | 32.85 | 40 | 5.1 |
| 2004 + | 160 | 16 | 10 | 11, 616 | 51.34 | 80 | 5.0 |
| 2005 + | 220 | 25 | 35 | 25, 606 | 132. 47 | 175 | 5.2 |
| 2006 + | 120 | 22 | 32 | 23, 958 | 81.18 | 154 | 5.1 |
| 2009 * | 18 | 1 | 5 | 4,806 | 14.81 | - | 2.4 |
| 2010 * | 31 | 2 | 10 | 8, 608 | 18.61 | - | 4.3 |

+ Usage in Niger S

## Conclusions

Having determined the impact of using power tiller for '*sawah*' for a period of five years at Ejeti and Shaba-Maliki and for two years at Ajase Ipo, it is evident that power tiller is the appropriate machinery for mechanization of lowland rice production. It is obvious that the power tiller is able to carry out both primary and secondary tillage operations and is most suitable for operations under wet conditions and for small holdings. Given the right set of implements and attachments, the power tiller is capable of performing most field operations under intensive cultivation of '*sawah*' rice. The light weight of the power tiller is a favourable factor for working in wet land conditions of '*sawah*' fields as it does not sink and creates least disturbance to soil structure. It is also relatively cheaper. In view of the above attributes, it is recommended that the power tiller has an advantage over heavier machinery (tractors)that farmers cannot afford to invest their money in it. Power tillers are therefore appropriate alternatives for most farmers in developing countries like Nigeria. With mass adoption of power tiller use, local artisans can learn to manufacture simple components of the machine, giving rise to employment opportunities for many people.

**References**

Aboaba, F.O. 1965. Some aspects of mechanization costings in Nigeria. Proc. Agr. Soc. Nigeria (1965) 4:26-30.

Crosceley, C.P. 1978. Theoretical design of small tractors. Paper presented at the Spring National Conference of the Institution of Agricultural Engineers, the National College of Agricultural Engineering, Silsoe, Bedford, 21 March, 1978. Pp 35-38

Fashola, O.O., Oladele O.I., Alabi, M.O., Tologbonse, D. and Wakatsuki, T. 2007. Socio-economics factors influencing the adoption of 'sawah' rice production technology in Nigeria. Journal of Food, Agriculture and Environment (JFAE) (2007) (1): 239-242.

Fashola O. O., Ademiluyi Y. S., Faleye T., David J. and T. Wakatsuki, 2007. Machinery systems management of walking tractor (power tiller) for rice production ('*sawah*') in Nigeria. Journal of Food, Agriculture and Environment (JFAE) (2007) (5): 283

Lambe, T.W. 1951. Soil Testing for Engineering. John Wiley and Sons Inc., New York. 1951. p. 33

WARDA 1988: Strategic plan 1990 – 2000. p.11.

# Challenges and Prospects of Youth Involvement in 'Sawah' Rice Farming in Nigeria

Olanrewaju, J.S.[1], Dada-Joel O.T[2], Onyemize, U.C[2], Fagbenja, M.A[2] Ademiluyi Y.S.[2] and Wakatsuki T[3].

[1]*New 'Sawah' Project, NCAM, Ilorin, Nigeria;* [2]*National Centre for Agricultural Mechanization, (NCAM), P.M.B 1525, Ilorin, Nigeria;* [3]*Department of Ecological Engineering, Faculty of Agriculture, Kinki University, Nara, Japan.*
*E-mail:*jolaseye@yahoo.com

*Abstract*

Nigeria has reached a very critical point in agriculture because many of our farmers who grow the bulk of locally produced food are very old. If not addressed, food security in Nigeria and most parts of Africa would reach a crisis point. The challenge is getting young people to be involved in agriculture. Meeting this challenge, with particular reference to 'Sawah' Eco-technology and Rice Farming (SERIF,) has encountered some experiences and constraints in the past and if not quickly addressed may retard efforts of the nation and region in providing solutions to food insecurity, environmental problems and poverty. This paper examines some of the experiences, challenges, constraints as well as the prospects of youth involvement in 'Sawah' rice farming and provides recommends on the way forward.

**Key words:** challenges, eco-technology, prospects, rice, farming, 'sawah', youth.

## Introduction

Nigeria with a population of over 140 million people (NPC, 2006) has an abundant human and natural resources for agricultural production. UNICEF (2008) reported that about 76% of Nigeria population lives in the rural areas and about 90% of the rural dwellers are engaged in agricultural production. However, irrespective of this array of advantages, the goal of self-sufficiency in food production in Nigeria remains elusive. According to Nwachukwu (2008) "one of the problems for non-realization of our goal for food sufficiency is the condition of the Nigerian farmer and the farming environment". The Nigerian farmer is ageing with an average of 50 years. The problem with this is that the younger generation is not interested in farming. The age and low level of education of the average Nigerian farmer correlates with his/her aversion of risks associated with the adoption of new innovations and hence the very low productive capacity. In the opinion of many, getting the youth to take up farming seems a possible panacea to the problem. According to Jibowo and Sotomi (1996), it is expected that with higher level of education, innovation, minimal risk aversion, greater physical strength and less conservativeness, Nigerian youth active and effective participation in agriculture would ensure adequate food production for the country.

Available evidence suggests an ageing farming population in Nigeria, with an average age of 47 years (NBS 2008, Oboh et al., 2009). In 2009, the national unemployment rate was 19.7% with the youth accounting for more than 75% (NBS, 2010). Increased involvement of the youth in agricultural activities would help to, not only solve the problem of ageing farmer population but would also reduce youth unemployment.

The World Bank reports that global food prices rose 83% over the last three years and the Food and Agriculture Organization cites 45% increase in their world food price index during the past nine months (Eric and Loren, 2008). Bio fuels have also forced global food prices up by 75% more than previously estimated. Grains have been diverted away from food to fuel. For example, over a third of U.S corn is now used to produce ethanol and about half of vegetable oil produced in Europe goes into the production of bio diesel (Aditya, 2008). The implication of this recent trend is that, developing countries like Nigeria whose economy solely relies on importation of grains (particularly rice), for the feeding of their teeming populations have to go back to the drawing board to formulate more pragmatic policies capable of turning the food production pendulum back to their side.

The youth at present, constitute about 60% of Nigeria's population and have over the years made significant contributions to National Development (Vision 2010 report, 2005). Unfortunately, the present environment makes it even more difficult to explore their full potential in agricultural production. In order to stimulate the interest of our youth in agricultural production; government has to put in place certain measures that will eliminate the associated constraints in the sector. Despite the fast growing opportunities in this sector, it is alarming and quite incredible to see many rural youths opting out of farming in search of non-existed white-collar jobs in the cities, leading to unprecedented level of rural-urban migration. This is obviously a serious threat to the aspiration of government to achieve food security by 2015. For sustainable agricultural development in Nigeria, there is an urgent need for a more rapid transformation from subsistence farming to a more commercialized one, involving the application of modern technology (Adisa, 2005) such as the 'Sawah' eco-technology for rice production.

### Challenges of Youth Involvement in 'Sawah' Rice Farming

Young people do not want to go and farm like some of our parents and grandparents did using outmoded tools and machinery. The youth need strong incentives to come into agriculture. Therefore, young scientists, technologists and other professionals have to be involved in agricultural production, processing and marketing through effective and stimulating packages. Scientific inventions/interventions that would ensure massive production, preservation and storage which would translate into profitability are needed. This will attract the youth into agriculture and help reduce unemployment and the brain drain.

### Constraints to Youth Involvement in SERIF

These constraints have been identified primarily through surveys (Adekunle et al. 2009). From the literature review, there are economic, social and environmental factors reducing rural youth involvement in agricultural production in Nigeria (Table 1). Economic factors include inadequate credit facilities, low farming profit margins, a lack of agricultural insurance, initial capital and production inputs. Social factors include public perception about farming and parental influence to move out of agriculture. Environmental issues include inadequate land, continuous poor harvests, and soil degradation. These findings are largely in agreement with the results obtained from other interviews conducted with selected youth leaders. The results further reveal that economic-based constraints seem to be the most important factors.

Another constraint is on policy. Policies are implemented by one government and then abandoned when a new government comes or even reversed completely. This is very costly and painful to our farmers, youth and businesses. So, policies reversal, poor or non-implementation of policies is a risk factor to agriculture. The solution to this is for governments to allow a bottom up approach in deciding policies. Constitutionally supported policies which are policies coming from the grassroots, communities, business people, farmers are supported by the people and they tend to make the desired impact.

**Table 1:** Constraints to Rural Youth's Involvement in Agriculture

| Constraints | Mean | Ranking |
|---|---|---|
| Inadequate credit facility | 2.88 | 1 |
| Poor returns to in vestment | 2.67 | 2 |
| No agricultural insurance | 2.67 | 2 |
| Poor basic farming knowledge | 2.57 | 3 |
| Insufficient access to tractors & other farm inputs | 2.48 | 4 |
| No ready market | 2.35 | 5 |
| It is energy -sapping | 2.33 | 6 |
| People perception | 2.28 | 7 |
| Insufficient initial capital | 2.15 | 8 |
| Farmers are not respected | 2.10 | 9 |
| Non - lucrativeness of agriculture | 2.03 | 10 |
| Continuous poor harvest | 1.94 | 11 |
| Poor storage facilities | 1.93 | 11 |
| Insufficient of land | 0.97 | 12 |
| Soil degradation | 0.66 | 14 |

**Source: Derived from Adekunle et al., 2009**

## Prospects of Youth Involvement in SERIF

Nigeria's government has attempted to stimulate youth's interest in agriculture (production and processing) since the late 1980s. In 1986, the federal government established the National Directorate of Employment (NDE) to provide vocational training for the youth. In 1987, the Better Life Programme was created to empower women, especially female youth in rural areas through skills acquisition and healthcare training. In addition, the People's Bank and the Community Banks were established in 1989 and 1990 respectively, to provide credit facilities to low income earners embarking on agriculture and other micro enterprises, with speciality for the youth. In 1992, the Fadama program was initiated to enhance food self-sufficiency, reduce poverty, and create opportunities for employment for the youth in rural areas. In 2004, the Ondo State government initiated a program called "Youth in Agriculture" and in 2008 the Akwa Ibom State government initiated an integrated farming scheme for newly graduated agricultural students. It set up a micro-credit scheme for youth engaged in agriculture. Other state governments also initiated graduate and school-leaver's agricultural loan schemes in an attempt to encouraged the youth to go into agriculture, empower those already engaged in agricultural activities and reduce youth unemployment. Despite these incentives and the expanding markets for primary and secondary agricultural commodities, the involvement of the youth in agricultural activities has steadily declined in recent years (Adekunle et al. 2009).

## Conclusion

Despite the predominance of rain-fed agriculture in Nigeria, the 'Sawah' system for use in the inland valleys will enhance continuous cropping and better use and distribution of the production activities. 'Sawah' is multi-functional and can greatly contribute to realizing the green revolution as well as the restoration of our fragile ecological environment. Itemized below are the benefits of 'Sawah' technology to Nigerian Agriculture: (i) technology has the capacity to increase youth participation in farming, (ii) Lowland 'Sawah' farming utilizes geological and irrigation fertilization resulting from mineralization of nutrients and translocation due to movement of top soil from upland, (iii) 'Sawah' will help combat global warming and other environmental problems, (iv) Carbon sequestration through control of oxygen supply. Methane emission under submerged condition, nitrous oxide emission under aerobic rice will be reduced, (v) De-nitrification of nitrate polluted water will be reduced, (vi) Watershed agro-forestry, SATOYAMA describes active 'Sawah' in the lowland and forestry in the upland; this encourages conservation of the environment, forest generation, enrichment of the lowland through various geological processes, (vii) 'Sawah' contribute to control of flooding and soil erosion and also has potential to generate hydro-electricity, (viii) In communal settings 'Sawah' promote fare water distribution systems for collaboration and fare society, (ix) 'Sawah' can significantly contribute to the current rehabilitation activities in the Niger Delta of Nigeria. The youth of Nigerian therefore have a lot to gain if they can participate in the 'Sawah' Eco-technology system which has the potential to transform the agricultural sector through boosting rice production and alleviating poverty.

## References

Adekunle, O. A., L. L. Oladipo, F. O. Adisa, R.S., Fatoye, A. D., (2009). Constraints to Youth's involvement in agricultural production in kwara state, Nigeria. Journal of agricultural extension, vol. 13(1), Pp 102-108.

Adisa, R. S. (2005). Zimbabwean Farmers and the Future of Agriculture in Kwara State, *The Herald*, 18th February, 2005

Aditya, C. (2008): Secret Report: Bio fuel caused food crisis, Internal World Bank study delivers blow to plant energy drives. *The Guardian* July 4, 2008.

Eric, H. G and Loren, P (2008): From food Rebellions to Food Sovereignty: Urgent Call to Fix a Broken Food System, Institute for Food and Development Policy, May, 16 2006.

Jibowo, A.A. and Sotomi, A.O. (1996). The Youths in Sustainable Rural Development. A Study of Youth Programs in Odeda Local Government Area of Ogun State. In: Ladele, A.A. et al (Eds). Policy Advocacy Role in Agricultural and Rural Transformation in Nigeria. Proceedings, 17th Annual Congress of the Nigerian Rural Sociological Association (NRSA), NRCRI, Umudike, 19th-22nd August.Pp. 54-57.

National Bureau of Statistics (NBS): Publications 2008 and 2010.

National Population Commission (NPC), (2006). National Population Estimates. Abuja, Nigeria

Nwachukwu, I (2008). Youth Development for Agriculture and Rural Transformation in Nigeria. Proceedings of NRSA, pp.11-14.

Oboh, V., and R. M. Sani, (2009). The role of radio on the campaign against the spread of HIV/AIDS among farmers in Markudi, Nigeria. Journal of social sciences, vol. 19 (3): 179-184.

UNICEF (2008). Draft Country Program document, Nigeria. E/ICEF/2008//P/L.7. UNICEF, Enugu.

Vision 2010 Report (2005): Youth, Development and Empowerment.

# SECTION THREE

# WORKSHOP RECOMMENDATIONS AND WAY FORWARD

## 1.0 Introduction:

Rural poverty and food insecurity can be partly attributed to degradation of land resources and lack of improved technologies. Throughout the West African sub-region, it is the small-scale farmer that produces the bulk of the food requirements of the people. The over reliance on the small scale farmer to produce the bulk of food required for an ever increasing population is a key factor for food insecurity in most countries. Major constraints to food production include declining soil fertility, poor support to resource poor farmers and luck of clear-cut land use policies. To reverse rural poverty the enabling environment needs to be created to encourage income generation in the rural areas, increase food production and security and protect the environment from degradation (Sanchez et al, 1997). Among the recommendations for achieving increased rice production in West Africa (AICAF, 1995) are improving rice growing technologies (optimum fertilizer usage, effective nutrient and water management options, use of high yielding varieties).

Over the years, although considerable progress has been made in addressing some of the problems confronting the rice growing industry within the sub-region, there is still the need to develop simple, low cost and environmentally friendly systems for managing the inland valley ecosystem that can be adapted by resource-poor farmers. This led to the development of the "Sawah" eco-technology.

## 2.0 What is "Sawah" Eco-technology

In developing any scientific technology, greater consideration should be given to both increased productivity and environmental friendliness. In other words, current production technologies should not only aim at higher productivity (yields) but also environmentally friendly (sustainability). In order to apply such scientific technologies, farmers' have to develop typically refined rice growing environments referred to as "Sawah" or develop similar alternatives which can conserve soil and control water. The term "sawah" refers to a leveled, bunded and puddled rice field with inlets and outlets for water management. Essential components of such land development are:

(i) demarcation by bunding based on topography, hydrology and soils,

(ii) leveling and puddling to control and conserve soil and water, and

(iii) water inlets and outlets. The above parameters are typical characteristics of "Sawah" fields. The essence for this is to avoid too much water collecting at one side of the field to the disadvantage of other parts of the field. "Sawah" can broadly be classified into several types; (i) spring type, (ii) dyke/weir – canal type, (iii) rain fed type, (iv) pump type (v) integrated type when two or more of the above types are used in combination. Local materials such as sand bags, bamboo sticks, wood etc are used to construct weirs/ dykes to harvest water.

## 3.0 Why "Sawah" Eco-technology

In Sub-Saharan Africa (SSA), even though there have been research concepts to improve Natural Resource Management (NRM), no clear research concept has been developed on how to improve natural resources such as soil and water conditions at the farmers' field level. The "Sawah" eco-technology is one of such missing concepts to improve natural resources management in majority of African rice farms. It can accelerate improvements in effective natural resources management, minimize environmental degradation and increase soil productivity in majority of African conditions. Of all lowland types available in the sub-region, inland valleys and to some extent flood plains have a comparative advantage because of relatively easy water control. However, African lowlands are quite diverse. Therefore careful site-specific development and management technologies are needed for their effective and sustainable utilization. The development of such technologies and their management by local farmers through self propelled efforts and the use of small-scale equipment such as power tillers are very prudent under African conditions.

## 4.0 Advantages of "Sawah" Eco-technology

The "Sawah" eco-technology can improve fertilizer and irrigation efficiency. Thus it can minimize the effect of water shortage, poor nutrition especially for nitrogen and phosphorous supply, neutralize acidity as well as alkalinity, and improve micronutrient supply. With this, improved varieties can perform well for the realization of the Green revolution in Africa. Thus the "sawah" eco-technology is the prerequisite condition for the three green revolution technologies to be successful. The "Sawah" system of rice production therefore seeks to improve on lowland rice production by helping to effectively manage land, control water and nutrients to boost local rice production. The lowland "Sawah" can also sustain rice yields (> 4-6t/ha) through macro scale natural geological fertilization from upland and micro-scale mechanisms to enhance supply of various nutrients. If appropriate lowlands are selected, developed and soil and water managed properly, then the application of improved agronomic practices such as System Rice Intensification (SRI) under the "Sawah" systems, can result in paddy grain yields exceeding 10 t/ha. Use of the technology can increase rice production from about one ton per hectare under the current traditional system to over four tons per hectare. It is also environmentally friendly and it minimizes erosion, reduces land degradation and increases nutrient-use-efficiency.

## 5.0 The Way Forward:

After a lengthy discussion involving academics, scientists, farmers, extensionists and policy makers, it was agreed by a general consensus that the introduction, adoption and endogenous evolution of the "sawah" system is appropriate. The introduction and adoption of the "sawah" technology, in some countries, particularly Ghana and Nigeria, has gone deep into the various communities and rice farmers. The general agreement was that, there is the need for a political will and support for the technology to be adopted on a larger scale in order to produce the expected results and make an impact on local rice production. Political will specifically mentioned was effective policy on "sawah" adoption in the lowlands for effective soil, nutrient and water management. Areas mentioned under government support includes acquisition of necessary machinery and parts such as power tillers to promote and encourage mechanization in the rice sector.

- The need for a good evaluation and monitoring system to prevent farmers from diverting donor/government support to other ventures.
- The need to build the capacity of extension workers and "sawah" farmers by providing them with good "sawah" training and working manuals. This will help MoFA to strengthen its education of farmers on "sawah".
- The need for a comprehensive development strategy for "sawah" expansion through the sensitization of farmers on the technology and the involvement of "sawah" scientists in national rice policy development.
- The need to support farmers in land acquisition. That the farmer be made to contribute to the investment in his/her "sawah" development so as to take ownership.

## 6.0 Recommendations.

We the participants (farmers, scientists, extensionists, policy makers, academics) at the 1st international workshop held at the Golden Tulip hotel, Kumasi, Ghana from 22nd -24th November 2011:

- Aware of the importance of agriculture to the countries socio-economic development and well-being of the people of Ghana, and beyond.
- Noting the low agricultural production, particularly rice, as a result of continuous soil, land and environmental degradation resulting mainly from soil fertility decline, soil erosion and also a breakdown in the traditional fallow system of maintaining soil fertility,

- Convinced that there is no proper and effective land use policy in the country and that the present land tenure system is inimical to the adoption of improved and appropriate technologies for soil and water management by our resource-poor farmers,
- Convinced that there is lack of public awareness about the soil as the foundation of agriculture,
- Convinced that the demand for rice will continue to rise in the immediate, medium and long term and that large amounts of foreign exchange will continue to be used on rice imports,
- Convinced that Africa, and in particular West Africa including Ghana, has large stretches of lowlands which can be used for rice production across most agro-ecological zones which can significantly reduce imports and create employment,
- Convinced that there is the urgent need for the adoption of improved and sustainable technologies for the rapid expansion of local rice production in the sub-region,

*Strongly recommend the following*:

(6.1) *To Government of Ghana (GoG)*

i. Formulate policies that will enhance agricultural production with minimum damage to soil and environment.

ii. Review and/or formulate and implement, as a matter of urgency, proper and effective land use policies in accordance with current and future imperatives for land conservation and sustainable agricultural productivity.

iii. Critically review the current land tenure system, and make it more investor friendly and establish land banks for effective land use planning.

iv. Support the Soil Research Institute of the Council for Scientific and Industrial Research, to conduct detailed soil investigations and hydrological investigations on lands that are found to be suitable for rice cultivation in particular. Collaboration with other CSIR Institute may be necessary.

v. Make suitability assessment of any lands earmarked for rice production mandatory and prerequisite to the granting of loans or any support.

vi. Ensure that areas earmarked for special rice projects are properly assessed for their suitability. Recommendations from such studies should be judiciously implemented in order to minimize degradation.

(6.2) *To the Ministry of Food and Agriculture (MoFA):*

i. As a matter of urgency, encourage and promote (out-scale) the adoption of "sawah" eco-technology as an effective and sustainable technology for rice cultivation particularly within the lowlands.

ii. Liaise with relevant stakeholders to encourage, promote and support mechanization in the rice sector especially small and medium scale farmers.

iii. Establish a unit with qualified soil scientists within the Ministry to address soil issues effectively.

iv. Liaise effectively with the CSIR in the execution of rice projects particularly in the fields of soil, nutrient and water management (natural resource management).

v. Encourage farmers to adopt land conservation and soil fertility enhancement practices for increased productivity particularly rice cultivation.

(6.3) *To Ministry of Environment, Science and Technology (MEST):*

i. Resource the CSIR-Soil Research Institute (SRI) and CSIR- Crops Research Institute (CRI) to enable them conduct more detailed studies particularly at areas found to be suitable for rice production.

ii. Help in improving laboratories at the CSIR-SRI to be able to monitor and analyze soil conditions for effective management interventions.

iii. Ensure that materials imported into the country (e. g. fertilizers and other agro-chemicals), are tested for their efficacy by the CSIR relevant Institutes.

iv. Ensure that any Environmental Impact Assessment and subsequent evaluation would involve Soil Scientists.

# LIST OF PARTICIPANTS

## BENIN

Shin Abe
Soil Scientist,
Africa Rice Center, 01 BP 2031,
Cotonou, Benin.
E-mail: s.abe@ cgiar.org
Tel: (229)21350188

Kpodonou Hector
Agricultural Extension Officer,
Glazoue region, Benin
E-mail: heckpo@yahoo.fr

Babadoudou-Akpodi N. J.
AnselmeAgricultural Extension,
Officer,Ouinhiregion, Benin
E-mail: Jodbab2@yahoo.fr

Gbaguidi Leopold
Agricultural Extension Officer,
Parakouregion, Benin

Dembele Youssouf
Development Officer,
Africa Rice Center, 01 BP 2031,
Cotonou, Benin.
E-mail: Y.Dembele@ cgiar.org

Sander Zwart
Research Scientist/SMART IV Coordinator
Africa Rice Center, 01 BP 2031,
Cotonou, Benin
E-mail: S.zwart@cgiar.org

Awadjetinde Amoussou Andre
Agricultural Extension Officer,
Savalou region, Benin

Gbangou B. A. Nassirou
Agricultural Extension Officer,
Kouande Region, Benin

Danvi Alexandre-Eudes
Research Scientist,
Africa Rice Center, 01 BP 2031, Cotonou,
Benin
E-mail: Danvi.alexandre@gmail.com

## GHANA

Hon. Sherry Ayitey
Minister,
Ministry of Environment, Science and
Technology,
P. O. Box M232. Accra, Ghana
E-mail:info@mest.gov.gh
Tel: 0302-662626

Abdulai B. Salifu
Director-General,
Council for Scientific and Industrial
Research (CSIR),
Head Office,
P. O. Box M. 32, Accra, Ghana
E-mail:dgsoffice@csir.org.gh
Tel: 0302-777651-4

Mohammed M. Buri
Principal Research Scientist /
'Sawah'Project Coordinator
CSIR – Soil Research Institute,
Academy Post Office, Kwadaso, Kumasi,
Ghana
E-mail: moro_buri@yahoo.com
Tel: 020818663

Joseph O. Feninig
Director,
CSIR – Soil Research Institute,
Academy Post Office, Kwadaso,
Kumasi, Ghana
E-mail: kofifening@yahoo.com
Tel: 0208175962

Oscar Amankwah
NyameAkwan Rice Farmers,
P.O Box 38, Nkawie, Ashanti Reg. Ghana.
Tel: 0546735522

Josephine Amo
Ministry of Food & Agriculture,
P. O. Box 65. Nkawie, Ashanti Region,
Ghana.
E-mail: makakedisposable@yahoo.com
Tel: 0243857207

Edward Calys-Tagoe
CSIR-Soil Research Institute,
Academy Post Office, Kwadaso,
Kumasi, Ghana
E-mail: calystagoe@yahoo.com
Tel: 0244685809

Kwame Osafredu Asubonteng
CSIR-Soil Research Institute,
Academy Post Office,
Kwadaso - Kumasi, Ghana.
E-mail: drasubonteng1@yahoo.com
Tel: 0208182735

Frank Otoo
Ministry of Food & Agriculture/JICA.
P. O. Box 112 Nyinahin.
Ashanti, Ghana.
Tel: 0543-184620

Hillary Mireku Bortey
CSIR-Crops Research Institute,
P. O. Box 3785, Fumesua - Kumasi, Ghana.
E-mail: hillarymireku@yahoo.co.uk
Tel: 0242380003

Thomas Awini
Asongtaba Rice Farmers Association
c/o P.O Box 65 Nkawie-Toase,
Ashanti Region Ghana.
Tel: 0241135012

Osei Boansi Issac
Ministry of Food & Agriculture,
P.O. Box 54, AhafoAno South,
Mankranso Ashanti, Ghana.
Tel: 02462126751/0276166703

Thomas Odei
Ministry of Food & Agriculture,
P. O. Box 54, AhafoAno South,
Mankranso - Ashanti, Ghana.
Tel: 0246578195

Abukari Neindow Daniel
Ministry of Food & Agriculture ,
Central Gonja, Buipe,
Northern Reg. Ghana.
E-mail: abukarinein@yahoo.com
Tel: 0245828495

Regassa Namara
International Water Management
Institute (IWMI), PMB CT 112
Cantonment, Accra, Ghana
E-mail: r.namara@yahoo.com

Awoonor Johnny
CSIR-Soil Research Institute,
Private Mail Bag,
Kwadaso-Kumasi, Ghana
E-mail: johnnyawoonor@yahoo.com
Tel: 0208085288

Kwabena Kankam-Yeboah
CSIR-Water Research Institute,
P.O. Box AH 38,
Achimota- Accra, Ghana.
E-mail: Kyeb59@yahoo.com
Tel: +233(0)248305981

George Kwesi Acheampong
CSIR-Crops Research Institute,
P .O. Box 3785, Kumasi, Ghana
E-mail: ageorgekwesie@yahoo.com
Tel: 0207893391

Sulemena Neindow
Ministry of Food & Agriculture,
Central Gonja, Buipe, Northern Reg. Ghana.
Tel: 0247525500

Monica Blankson Asiedu (Mrs)
CSIR - Soil Research Institute,
Academy Post Office, Kwadaso, Kumasi, Ghana.
E-mail: Monicaasiedu@yahoo.com
Tel: 0208139987

Thomas Nsowah Adjei
Ghana Broadcasting Corporation (GBC),
P. O. Box 1963, Kumasi, Ghana.
E-mail: thomasnso wahadjei@yahoo.com
Tel: 0245764701

Alfred Amoh
District Director,
Ministry of Food & Agriculture,
P.O. Box 54,
Ahafo Ano South, Mankranso
Ashanti, Ghana
Tel: 0242679761

Ato Essien
Chief Technical Officer,
CSIR-Soil Research Institute,
Academy Post Office, Kwadaso,
Kumasi, Ghana
Tel: 0244799269

Amoakwah Emmanuel
CSIR-Soil Research Institute,
Academy Post Office, Kwadaso,
Kumasi, Ghana.
E-mail: emmaamoakwah@yahoo.com
Tel: 0244350543

Victor Owusu-Ansah
District Development Officer,
Ministry of Food & Agriculture,
P.O Box 54, Ahafo Ano South,
Mankranso, Ashanti, Ghana.
E-mail: v-owusuansah@yahoo.com
Tel: 02086399338/032209495

Lawrence Kumah
The Lens,
P. O. Box 1223 Kumasi or
P.O Box KN2608 Accra Kaneshie, Ghana.
E-mail: lawrencekumah123@yahoo.com
Tel: 0244022784/0274862534

Doris K Puozaa
Research Scientist,
CSIR - Crops Research Institute.
P. O. Box 3785,Fumesua, Kumasi, Ghana.
E-mail: doriskanp@gmail.com
Tel: 0541459602

Kwabena A. Nketia
Research Scientist,
CSIR-Soil Research Institute, P.M.B.
Academy Post Office,
Kwadaso -Kumasi, Ghana.
E-mail: Kanj241@gmail.com
Tel: +233327050308/+233208278770

M. Owusu -Akyaw
Senior Research Scientist,
CSIR-Crops Research Institute,
P .O Box 3785 Kumasi, Ghana.
E-mail: mowusuakyaw@yahoo.com
Tel: 03220-50410/11 0244612398

Majeeb Rahman
Journalist,
METRO TV,
Ashanti Region Office, Kumasi, Ghana.
Tel: 0244541952

Morgan Owusu,
Journalist,
Daily Guide Newspaper,
P.O. Box 2406, Kumasi- Ghana.
E-mail: morganowusu@yahoo.com
Tel: 0322240957/0244

Shaibu Lasisi
Journalist,
Ash FM Radio station,
P. O. Box 2466, Ash-Town,
Kumasi, Ghana.
E-mail: lasisi03@yahoo.com
Tel: 0205445454/0244715291

Alafao Mohammed
Farmer,
Amoakokrom Rice Farmers Association,
Amoakokrom, Ahafo Ano South District,
Ashanti Reg. Ghana.
Tel: 0206318691

Adu-Tawiah
Lead Farmer,
Club C Rice Farmers Group, Adugyama
Ahafo Ano South District, Ashanti Region,
Ghana.
Tel: 0244145154

Mr. Michael Osei
National Security,
The National Security Coordinator
P.O. Box 3850 Kumasi
Tel: 0272554833

Francis A. Bediako
Farmer,
Sawah Farmers Group, Ahafo Ano South,
Potrikrom,
Ashanti Reg. Ghana.
Tel: 0274308557

Ishaku Atia
Farmer,
Essenkyem Rice Farmers Group, ,
Essenkyem,AhafoAno South District,
Ashanti Reg. Ghana.
Tel: 0206869859

Mr. Philip Adjei
Regional Rice Officer
Ministry of Food & Agriculture
(MOFA/IVRDP),
P. O. Box 3820 Kumasi, Ghana
E-mail: padjei2004@yahoo.co.uk
Tel: 0322036586/0247855389

Kwabena Aupratwum,
Journalist,
Luv FM Radio Station,
PMB, Kumasi, Ghana
E-mail: kowusu.aupratwum@yahoo.com
Tel: 0208256619/0244784920

Antwi Bosiako Oscar,
Journalist,
Freedom FM Radio Station,
P. O. Box 63, Anloga, Kumasi-Ghana
E-mail: nanaboray@yahoo.com
Tel: 024471816/0322020093

Shaibu Mahama
District Director,
Ministry of Food & Agriculture,
P. O. Box 6, Ahafo Ano South,
Tepa, Kumasi – Ghana

E-mail: saibumahama@yahoo.com
Tel: 0244042507/0322047132

Michael Ofori Afriyie,
Journalist,
Ghanaian Voice Newspaper,
P. O. Box MP 514, Mamprobi,
Accra - Ghana
E-mail: michaelofosuafriyie@yahoo.com
Tel: 0242843903/0264657146

Alex Ababio,
Journalist,
Ghanaian Observer Newspaper,
P. O. Box 284, Kumasi - Ghana
E-mail: alexisababbio@yahoo.com
Tel: 0546797583

Suleman Mahama
Lead Farmer,
Achiber Rice Farmers Group, Biemso No. 1,
AhafoAno South District, Ashanti, Ghana,
Tel: 0246375160

Abdul Basit
Journalist,
METRO TV,
Ashanti Region Office, Kumasi, Ghana.
E-mail: Abdelbasit5@yahoo.com
Tel: 0244408597

Kofi Kankam
Project Coordinator,
Japan International Research Center for Agricultural Sciences (JIRCAS), Kumasi, Ghana.
E-mail: eri@erikabirra.org
Tel: 0322021413/0247661440

K. Asare Boadu
Journalist,
GRAPHIC Corporation Ltd,
P. O. Box 2109, Kumasi, Ghana

Yaa Asantewaa Frafra
Farmer,
Women Rice Farmers Group, Adugyama
AhafoAno South District,
Ashanti, Ghana.
Tel: 0244145154

George Owusu Ampratwum,
Journalist,
Daily Searchlight Newspaper,
P. O. Box 4507,
Kaneshie, Accra - Ghana
E-mail: ampratwumgeorge@yahoo.com
Tel: 0249933127/0244206890

Kwabena Nimo,
Journalist,
TV3, Kumasi Office,
P. O. Box K 8614, Kumasi, Ghana
E-mail: Kwabena7000@yahoo.com
Tel: 0244246358/0322035691

Bukari Musah
Farmer,
Sawah Rice Farmers Association,
Biemso No. 1,
AhafoAno South District, Ashanti, Ghana
Tel: 0549459490

Kwaku Manu,
Farmer,
Fedeyeya Rice Farmer Group, Fedeyeya,
Ahafo Ano South District,
Ashanti, Ghana

Mary Naako Bandoh (Mrs)
Research Scientist,
CSIR-Crops Research Institute,
P.O. Box 3785, Kumasi, Ghana.
E-mail: ammabandoh@yahoo.com
Tel: 0208242286

Roland Nuhu Issaka
Senior Research Scientist,
CSIR-Soil Research Institute,
Academy Post Office,
Kwadaso -Kumasi, Ghana.
E-mail: rolandissaka@yahoo.com
Tel: 0243286791

Seidu Adams
Farmer,
Sawah Farmers Association,
Ahafo Ano South,
Adugyama, Ashanti Reg. Ghana
Tel: 0246186452

Isaac Adu
Journalist,
The Enquirer Newspaper,
P. O. BoxD 90, Kumasi, Ghana.
E-mail: ijahmangh@yahoo.com
Tel: 0277729458

Joseph Yeng Faarlong
Regional Director,
Ministry of Food & Agriculture,
Northern Regional Directorate,
P. O. Box N. 37, Tamale, Ghana
E-mail: Joefaolong2000@yahoo.com
Tel: 0244704206/0202026414

Alhaji A. R. Z. Salifu
Deputy- Director,
Ministry of Food & Agriculture (MoFA),
Directorate of Crop Services,
P. O. Box M 37, Accra, Ghana.
E-mail: zsalifu@yahoo.co.uk
Tel: 0244381215

Ibrahim Adams
Farmer,
Nyame Bekyere Farmers Group,
Ahafo Ano South,
Amakom, Ashanti Region. Ghana.
Tel: 0540992474

Eric Owusu Adjei
Scientific Secretary,
CSIR-Soil Research Institute, Academy
Post Office, Kwadaso, Kumasi- Ghana.
E-mail: Erowad2003@yahoo.co.uk
Tel: 0244442919

Benjamin M. Adjei
National Program Assistant,
Food & Agriculture Organization (FAO)
Abdul- Gomel Street, Accra, Ghana.
E-mail: Benjamin.Adjei@fao.org
Tel: 0243562149

Kofi Attobrah
Journalist,
Ghana Television (GTV), Ghana
Broadcasting Corporation,
P. O. Box 1963, Kumasi - Ghana
E-mail: Kofi attobrah@yahoo.com
Tel: 0208154302/0322022331

Budu Hagan S.
Journalsit,
Ghana Television (GTV), Ghana
Broadcasting Corporation, P. O. Box 1963,
Kumasi - Ghana
E-mail: Solobudu20072@yahoo.com
Tel: 0242115965/0322022050

William Boakye -Acheampong
Regional Director
Ministry of Food & Agriculture,
Ashanti Regional Directorate,
P. O. Box 3820, Kumasi, Ghana
E-mail: wboakyeacheampong@yahoo.com
Tel: 03222036585/0244216918

Gifty Boakye
Agricultural officer
Ministry of Food and Agriculture,
P. O. Box 3820, Kumasi, Ghana.
E-mail: giftboakye@yahoo.com
Tel: 0244661452

E . Annan-Afful
Research Scientist,
CSIR-Crops Research Institute,
P. O. Box 3785, Kumasi, Ghana
E-mail: eannanafful@yahoo.com
Tel: 0322060390/1/0244781811

Agbaam Paschal
Agricultural Officer
Ministry of Food & Agriculture
(MOFA/JICA),
P.O. Box 14 Tamale, Northern Region,
Ghana.
E-mail: Agbaam@yahoo.com
Tel: 037202293/0244444227

Maxwell Adu-Poku
District Development Officer
Ministry of Food & Agriculture
(MOFA/JIRCAS)
P. O. Box 54, Mankranso-Ashanti. Ghana.
E-mail: maxwelladupoku@yahoo.com
Tel: 0243179964

Victor Vanderpuye
Journalist,
Ghana Television (GTV), Ghana
Broadcasting Corporation,
P. O. Box 1963, Kumasi - Ghana
E-mail: Victor_vanderpuye@yahoo.com
Tel: 0248878652

David Amoateng
Editor,
Weekly Observer Newspaper
Kumasi, Ghana.
E-mail: Weeklyobserver1@yahoo.com
Tel: 0243375759/0208157754

Kwame Agyekum,
Journalist,
Kumasi Mail Newspaper, Kumasi -
Ghana
0276320594/0276320594

Konadu Yiadom,
Accounting Officer,
CSIR - Soil Research Institute,
Academy Post Office Kwadaso-
Kumasi, Ghana.
E-mail: yiadom@yahoo.com
Tel: 020845755/0322050354

Kusi Adjei F.
Principal Technical Officer
CSIR - Soil Research Institute, Academy
Post Office Kwadaso- Kumasi, Ghana
E-mail: kus_frank@yahoo.com
Tel: 0244447449/032250353

Yaa Pokuaa,
Agricultural Officer,
Ministry of Food & Agriculture
(MOFA/JICA), P. O. Box 3820, Kumasi,
Ghana.

E-mail: ymaame@gmail.com
Tel: 0244113878/0322046132

Samuel Kissi,
Ministry of Food & Agriculture
(MOFA/JICA),
P. O. Box 3820, Kumasi, Ghana.
E-mail: samuelkissi@yahoo.com
Tel: 0243711425

Tiwaah Mercy,
Journalsit,
Freedom FM Radio Station
P. O. Box SE 2349, Suame-Kumasi, Ghana.
Tel: 0542171782

Peter Agyekum,
District Development Officer
Ministry of Food & Agriculture,
Nkawie -Ashanti, Ghana
Tel: 0545066735

Alhassan Abdul Rauf M
Extension Officer,
Ministry of Food & Agriculture
(MOFA/JICA), Regional Directorate,
P. O. Box 14, Tamale - Ghana
E-mail: malimanga2@yahoo.com
Tel: 0208340904/0372024497

Nathaniel Biney
Senior Technical Officer
CSIR-Soil Research Institute,
Academy Post Office, Kwadaso,
Kumasi, Ghana
Tel: 024-6336069

Justice PokuAddae
Accounting Officer,
CSIR - Soil Research Institute,
Academy Post Office, Kwadaso- Kumasi,
Ghana.
E-mail: justice.addae@yahoo.com
Tel: 0244856102

Edward Yeboah,
Research Scientist,
CSIR - Soil Research Institute,
Academy Post Office,
Kwadaso- Kumasi, Ghana.
E-mail: eyeboah5@yahoo.com
Tel: 233223740

Mumuni Eliasu,
Agricultural Officer
Ministry of Food & Agriculture
(MOFA/JICA),
P. O. Box 3820, Kumasi, Ghana
E-mail: mumumie@yahoo.com
Tel: 0267381672/0322046132

Anthony Amoa-Bosompem.
Ministry of Food & Agriculture,
P. O. Box 6, Tepa-Ashanti, Ghana.
E-mail: amoabosompem@yahoo.com
Tel: 0547535561/032047132

Tordzi Deborah
Journalist,
Freedom FM Radio Station
P. O. Box SE 2349, Suame-Kumasi,
Ghana
Tel: 0246914634

Christian Mawuli Teddy
Journalsit,
The Al-Hajj Newspaper, Kumasi - Ghana
E-mail: Gm.Teddy13@yahoo.com
Tel: 0242286341/0267600749

Aboagye Isaac Raphael
District Development Officer,
Ministry of Food & Agriculture, District

Directorate,
P. O. Box 65,Nkawie, Ashanti - Ghana
Tel: 0243835082

Raphael K. Bam
Senior Research Scientist,
CSIR-Crops Research Institute,
P. O. Box 3785, Kumasi, Ghana
E-mail: ralphbam@yahoo.com
Tel: 0322060390/0208173536

James Oppong
Research Scientist,
CSIR - Soil Research Institute,
Academy Post Office, Kwadaso,
Kumasi, Ghana.
E-mail: aofppong@yahoo.com
Tel: 0275319978

Yusuf Ahmed Tijani
Ministry of Food and Agriculture (MOFA),
P. O. Box 14, Tamale, Northern Region,
Ghana.
E-mail: Ahmedtijani3113@yahoo.com
Tel: 0372022983/0268573838

Kwabia Mensah,
Journalist,
Ghana News Agency (GNA),
P. O. Box 939, Kumasi, Ghana.
E-mail: Kwabiamensah@gmail
Tel: 0242553286

Al-Hassan Imoro
Desk Officer
Directorate of Crop Services,
Ministry of Food & Agriculture,
P. O. Box M 37, Accra - Ghana
E-mail:Hassan_umarr'yahoo.co.uk
Tel: 030266506/0242542185

Barffour Awuah Julius
Journalist,
Joeken Multimedia,
P. O. Box 99999, Kumasi, Ashanti, Ghana.
Tel: 0246132113

Edward Adu,
Journalist,
Joeken Multimedia,
P. O. Box 99999, Kumasi, Ashanti, Ghana.
Tel: 0246980471

Moro Dramani
Farmer,
Afresene Camp Rice Farmers Group,
Afresene Camp, Ahafo Ano South,
Ashanti, Ghana.
Tel: 0247856488

Joseph Ofori
E-mail: oforijos@yahoo.com
Tel: 0244678786

E. Owusu-Sekyere
Principal Research Scientist,
CSIR-Forestry Research Institute of
Ghana,
P. O. Box 63, KNUST-Kumasi, Ghana.
E-mail: eosekyere@csir-forig.org.gh
Tel: 0322060123/0244221849

Iddrisu Musah
Ministry of Food & Agriculture
(MOFA/JICA),
P.O. Box 14 Tamale, Northern Region,
Ghana.
E-mail: Iddrisu_musah@ymail. com
Tel: 03772027749/0243669042

Elizabeth Koranteng,
Journalist,
Ghana News Agency (GNA),
P. O. Box 939, Kumasi, Ghana.
E-mail: Amaasabea16@yahoo.com
Tel: 0266303551

William Osei
District Development Officer
Ministry of Food & Agriculture,
Atwima Mponua District,
P. O. Box 112, Nyinahin , Ghana.
E-mail: William.osei27@gmail.com
Tel: 0244076123

Ernest Best Anane
Journalist,
The Chronicle News Paper,
P. O. Box NT 4118, Kumasi, Ghana.
E-mail: Ernestbest95@yahoo.com
Tel: 0245361383

Suraj Salifu
Farmer,
Zuria Rice Farmers Group, Baniekrom,
AhafoAno South District, Ashanti, Ghana

Issaka Adam
Farmer,
Nyame Be Ye Rice Farmers Group,
Biemso No. 1, AhafoAno South District,
Ashanti, Ghana.
Tel: 0548759723

Samuel Tetteh,
District Development Officer,
Ministry of Food & Agriculture (MOFA)
P. O. Box 54, Mankranso-Ashanti. Ghana.
E-mail: Tsammy20032001@yahoo.com
0208556821

Benjamin Adiyiah
Research Scientist,
CSIR - Soil Research Institute,
Academy Post Office, Kwadaso- Kumasi,
Ghana.
E-mail: benjaminadiyiah@yahoo.com
Tel: 0273547215/50353/4

Hectori Hanker (Mrs)
Administrative Officer,
CSIR - Soil Research Institute,
Academy Post Office Kwadaso-
Kumasi, Ghana.
E-mail: Hecty268@yahoo.com
Tel: 0208159501

Ernest Okai,
Journalsit,
TV3, Kumasi Office,
P. O. Box K 8614, Kumasi, Ghana
E-mail: okaique@yahoo.com
Tel: 0243926570/0332035691

## INDONESIA

Darmawan
Professor
Andalas University, Padang,
West Sumatra, Indonesia.
Darmawan-dorma@yahoo.com

## JAPAN

Wakatsuki Toshiyuki
Professor / Sawah Leader
Faculty of Agriculture, Kinki University,
Nara 631 - 8505, Japan
E-mail:wakatuki@nara.kindai.ac.jp
Tel: +81-742-43-9250

Naoyoshi Kawano
Research Scientist
Japan International Research Center for Agricultural Sciences (JIRCAS), Owashi 1-1, Tsukuba City, Ibaraki, Japan.
E-mail: nakawano@affrc
Tel: +81296386678

Katsuyuki Ohara
Project Leader
Japan International Co-operation Agency (JICA), c/o Ministry of Food & Agriculture Regional Directorate,
Kumasi - Ghana
E-mail: ohara124@yahoo.com
Tel: 0543289446

Naoya Fujimoto
Research Scientist/Project Leader
Japan International Research Center for Agricultural Sciences
(JIRCAS), Owashi 1-1, Tsukuba City, Ibaraki, Japan.
E-mail: nfujimot@affrc.go.jp

Masaki Morishita
Japan International Research Center for Agricultural Sciences (JIRCAS),
Owashi 1-1, Tsukuba City, Ibaraki, Japan

Masanori Takemoto
Japan International Co-operation Agency (JICA), c/o Ministry of Food & Agriculture Regional Directorate, Kumasi - Ghana.
E-mail: masano.take@yahoo.com
Tel: 0544428692/0322046132

## NIGERIA

Ogunsola Aduyeni F.
Director
Lagos State Fadama Office, Lagos State Agricultural Development Complex,
OkoobaAgege , Lagos , Nigeria.
E-mail: ogunsola@isada.org
Tel: 08023389930

Agboola Adeniyi O.
Research Scientist
HIROSE PROJECT, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.
E-mail: n_agboola@yahoo.com
Tel: +2348060323226

Kolawole Ebenezer A.
Research Scientist
New Sawah Project, Ekiti State, Nigeria.
E-mail: ayorindeline@yahoo.com
Tel: +2348062848019

Mohammed Ayando F.
Research Scientist
National Centre for Agricultural Mechanization, PMB 1525, Ilorin, Kwara State, Nigeria.
E-mail: NCAM@yahoo.com
Tel: 08060094274

Nwite, John Chukwu
Research Scientist
Sawah Eco-Technology,
University of Nigeria, Nsukka, Nigeria.
E-mail: johnwhite4real_2007@yahoo.com
Tel: +234-8064170054

Segun Ademiluyi
Research Scientist,
National Centre For Agricultural
Mechanization (NCAM), PMB 1525,,Illorin,
Kwara State, Nigeria.
E-mail: segunncam@yahoo.com
Tel: 0803-6575232(+234)

Nwovu Chukwudi S
Director
National Fadama Co-ordination Office,
Abuja, Nigeria.
E-mail: sheddyu@yahoo.com
Tel: 08038773016

Tarngngu A. Kelvin
Director
Fadama III Project,
Benue State Fadama Coordination Office,
Dnarda Office, Makurdi, Benue State,
Nigeria.
E-mail: ktarnongu@yahoo.com
Tel: 08062945009

Adigbo S. O.
Research Scientist
CRP, IFSERAR,
University of Agriculture, Abeokuta,
Nigeria.
E-mail: sundayadigbo@yahoo.com
Tel: +2348062435720

Ovu, Chikodi Toby
Agricultural Officer
Sawah Eco-Technology For Rice
Production
University of Nigeria, Nsukka, Nigeria.
E-mail: ovuchikodi@yahoo.com
Tel: +234-8060187939

Adekunle -J- Adebayo
Research Scientist
National Centre for Agricultural
Mechanization,
P.M.B. 1525, Ilorin,Kwara State Nigeria.
E-mail: Jossy212@yahoo.com
Tel: +2348030462633

Baba Titus Sunday
Director
Sawah Eco-Technology for Rice
Production,
Niger State Agricultural Development
Project,
Minna, Nigeria,
E-mail: titusbu@gmail.com
Tel: +2348065325114

Asaolu Oluwadare J.
Agricultural Officer
Ondo State,Agricultural Development
Project,
Obafemi Awolabo, Alagbaka, Akure,
Nigeria
E-mail: Johnashaolu200@yahoo.com
Tel: +2347032201097

Tijani Lamidi Ayinla
Director
FCT Agricultural Development Project,
Along Fren Road New Market ,
P.M.B - 165 Sarki Gwagwalada–Abuja,
Nigeria.
E-mail: lamiditijani@yahoo.co.uk
Tel: 08036336516

Muhamal S. Augie
Director
Fadama III Project, Kebbi State, Nigeria.
E-mail: Msaugie59@yahoo.com
Tel: 08065263333

Peter Nwiphury
Farmer,
Ebonyi State Fadama Office
Ebony State, Nigeria

Ayodele A. Adeniyi
Director
National Fadama Coordinating Office,
Nafisa Plaza,
Central Business District, Abuja,Nigeria
E-mail: Aaadeniyiemail.com
Tel: +2348037860590

Herbert Bernard
Director
Fadama (NFCO) Central Area,
Garki-Abuja, Nigeria.
E-mail: Bherbert75@yahoo.com
Tel: 08037033455

Dada Joel O. Temitope
Research Scientist,
National Centre for Agricultural
Mechanization,
KM Ilorin-Lokoja Highway Idofian
PMB 1525, Ilorin, Kwara State, Nigeria.
E-mail: temidada@yahoo.com
Tel: +2348032224321

## SOUTH AFRICA

Oladele O. Idowu
Professor,
Dep't of Agricultural Econ.& Extension,
North-West University, Mafikeng Campus,
South Africa
E-mail: Olagele20002001@yahoo.com
Tel: 0786400504

## TOGO

Hougbedji Tossimide
Institute Togolais de Recherché
Agionomique (ITRA), BP. 1163,
Lome - Togo.
E-mail: Tossimde@yahoo.gh
Tel: +22891302851

Palanga Adje'em Modeste
Agricultural Extension Officer
Sotouboua region, Togo
E-mail: palmod@yahoo.fr

Gatzaro Atomn
Agricultural Extension Officer
Mission Tove region
Togo

Kerim A. Ayouba
Agricultural Extension Officer,
Lama Kara region- Togo
E-mail: kaayouba@yahoo.fr

Wegbe Fofo Auguste
Agricultural Extension Officer
Kpalime region - Togo
E-mail: wegbeauguste@yahoo.fr

Samie Amedi
Agricultural Extension Officer
Kara region - Togo
E-mail: samieagro@yahoo.fr