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 (FAO STAT). 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)

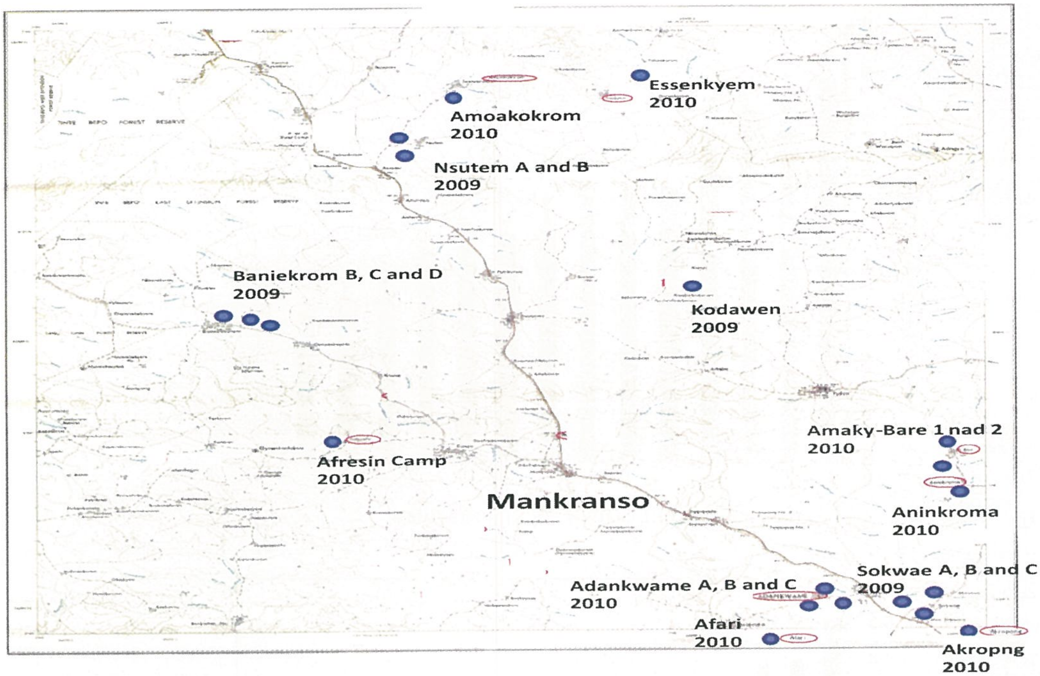
ii) Technical factors (Experience of rice cultivation, knowledge of rice cultivation)

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).

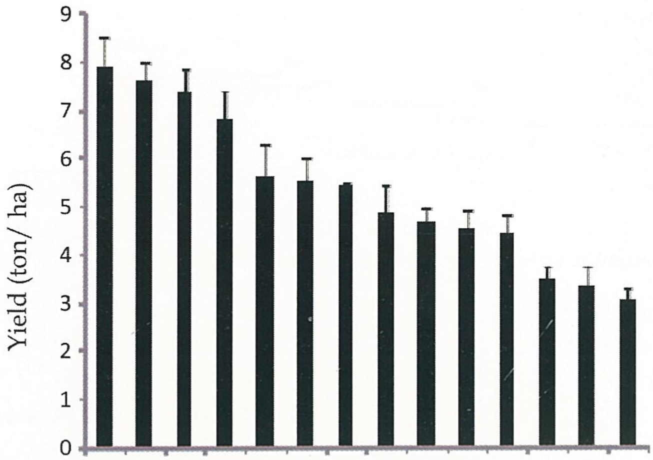


Fig. 2. Grain yield ($t\ ha^{-1}$) at various sites

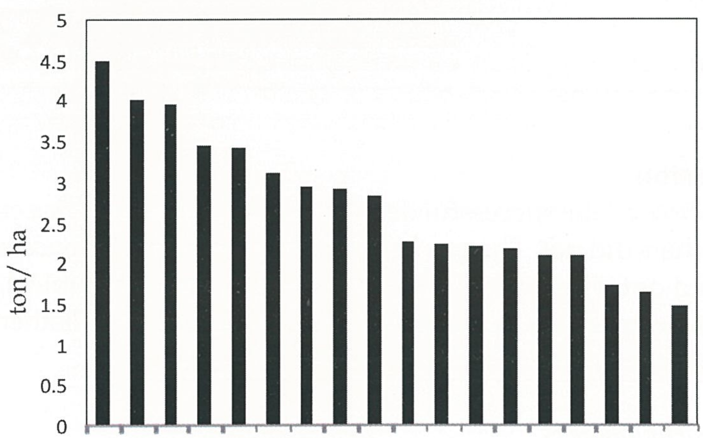


Fig. 3. Grain yield per unit area (1 ha) at the various sites

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.

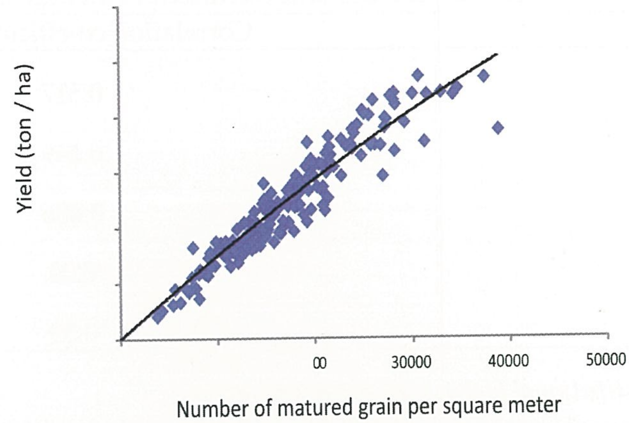


Fig. 4. Relationship between number of matured grain and grain yield.

(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 =

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

$R^2 = 0.60$

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.

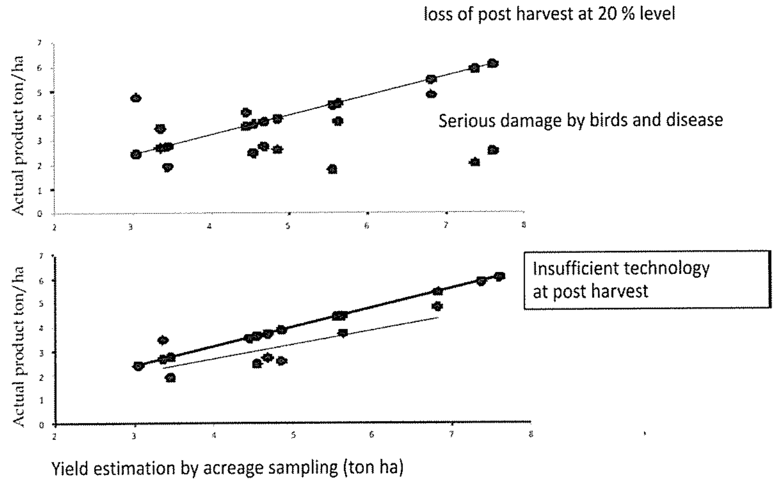


Fig. 5. Gab between actual and estimated yield.

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