LAND TENURE SYSTEM AND SOIL FERTILITY STATUS FOR ADOPTION OF SAWAH TECHNOLOGY IN NIGERIA AND GHANA

(ナイジェリアとガーナにおけるSawah技術採用のための、土地保有制と土壌肥沃度状態に関する研究)

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THE UNITED GRADUATE SCHOOL OF AGRICULTURAL SCIENCES, TOTTORI UNIVERSITY

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Approval Sheet

This thesis enclosed herewith, **"Land Tenure System and Soil Fertility Status for Adoption of Sawah technology in Nigeria and Ghana",** prepared and submitted by **ALARIMA Cornelius Idowu** in partial fulfilment of the requirement for the award of the degree of Doctor of Philosophy , is hereby approved as to style and contents.

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Dedication

This work is dedicated to:

My Late Parents; High Chief Raphael Adefemi ALARIMA and Mrs Phebean Moyosola ALARIMA for the sound up-bringing given to me.

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CHAPTER 1

General Introduction

1.10. Rice Production and Consumption in Nigeria

Nigeria was traditionally an agricultural country providing the bulk of its own food needs and exporting a variety of agricultural goods such as cocoa, rubber and many other cash crops. Up till the early 1960's, Nigeria was self-sufficient in food production (Ojo, 1991). The Nigerian agriculture, with a near total dependence on rain produced food and raw materials to the industrial sector of the economy. With varying agricultural ecologies, Nigeria produces different crops ranging from cash crops like cocoa, coffee, cola nut; tuber crops like yam, cassava, sweet potato; legumes like cowpea, ground nut and cereals like maize, rice, millet and guinea corn. As from 1970, with the oil boom, the decline in farming activities became more pronounced (Oludimu and Imoudu, 1998). There were widening food supply-demand gaps and rising food import bills (Falusi, 1990). The food self-sufficiency index- ratio of aggregate local food supply to the aggregate food demand fell (Rahji, 1999).

Mostly affected among these crops, with high import bill is rice. Rice is one of the most important crops consumed by all Nigerians irrespective of tribe and geographical location. Nigeria was virtually self-sufficient in rice in the 1960's and early 1970's, with imported rice playing an insignificant role in total rice supply and consumption in the country. The quantity imported was on average 1100 Mt for the 1960s and 5800 tonnes for the period 1970-1974. Import of rice however picked a pace from the year 1976 with an import quantity of 446,000 Mt. In 1990, Nigeria imported 224,000 metric tons of rice valued at US 60 million dollars. This increased to 345,000 metric tons in 1996 with a value of US130 million dollars. By 2001, rice import increased to 1.51 million metric tons valued at US288.1 million dollars (FAO, 1994). These figures indicate a 500 percent rise in foreign exchange expenditure on rice imports within eleven years.

Rice is an internationally consumed staple food cutting across all the continents in the world with Nigeria having great share of world's rice consumption. Rice is consumed by over 4.8 billion people in 176 countries and is the most important food crop for over 2.89 billion people in Asia, over 40 million people in Africa and over 150.3 million people in America with estimates based on FAO report of 1996 (Daramola, 2005). More than 90% of global production occurs in tropical and semi-tropical Asia (Daramola, 2005). Rice is a major staple food for millions of people in West Africa and the fastest growing commodity in Nigeria's food basket (Akande, 2003).

Nigeria is the largest producers and leading consumer of rice in Africa and simultaneously one of the largest rice importers in the world. Rice is a very important staple food in the diet of the estimated 120 million Nigerians. It is consumed in various forms but the most popular is as grains. However in recent times, domestic supply has not kept pace with demand as imports have steadily increased faster than domestic supply by accounting for close to 60% of total supply. Despite the high level of consumption of rice in Nigeria, production still remains low with high demand for imported rice. Nigeria consumes more than 5 million metric tons of rice annually. Annual domestic output of rice still hovers around 3.0 million metric tons, leaving the huge gap of about 2 million metric tons annually, a situation, which has continued to encourage dependence on importation (Daramola, 2005). Self-sufficiency in rice production is now an important political-economic goal of the Nigerian government (Bello, 2004)

Rice cultivation is widespread within the country extending from the northern to southern zones. Rice is produced in at least 35 of Nigeria's 37 States, covering three major ecological zones: rain-fed upland, rain-fed lowland and irrigated. Estimates by WARDA (1996), Singh et.al. (1997) and Imolehin and Wada (2000) put potential areas for rice production at 4.6-4.9 million hectares while actual areas under cultivation is 1.77 million hectares leaving a hug area of 3 million hectares uncultivated. A number of factors have been identified as responsible for this gap. Some of the reasons for the gap are connected with the improper production methods, scarcity and high cost of inputs like credit, imported equipment and agrochemicals due to taxes, high transportation costs, absence of extension advice, land tenure system, high cost of fertilizer, rudimentary post - harvest and processing methods, inefficient milling techniques and poor marketing standards particularly in terms of polishing and packaging. Also poor or low mechanization on rice farms means heavy reliance on manual labour to carry out all farm operations (Daramola, 2005). There is therefore a need to improve rice production in Nigeria.

1.11. Sawah Technology

In an effort to improve rice production and reduce over dependence on rice importation to meet the rice demand in Nigeria, sawah technology was introduced to the lowland inland valleys of Nigeria. Sawah refers to man-made improved rice fields with demarcated, levelled, bunded and puddled rice fields with water inlets and outlets which can be connected to various irrigation facilities such as irrigation canals, pond, springs or pumps. The term sawah originated from malayo – Indonesia. The English and French terms, paddy or paddi also originated from Malayo Indonesian term padi which means rice plant. Therefore in order to avoid confusion between upland paddy fields, and man-made levelled , bunded and puddled rice field that is, typically irrigated rice growing environment the authors propose to use the term "sawah" in SSA (Wakatsuki and Buri, 2008). Sawah concept composed of two hypotheses, i.e., Sawah hypothesis 1 (as a scientific platform) and Sawah hypothesis 2 (multi-functionality for intensive sustainability through micro-scale mechanisms in a sawah plot and macro scale mechanisms in watershed scale). Lowland sawah systems can sustainably produce paddies at approximately 2 t/ha without any chemical fertilizer application (Hirose and Wakatsuki 2002, Wakatsuki et al. 2009). Furthermore, lowland sawah systems can support rice cultivation continuously for decades, centuries, or more without any fallow period. According to Wakatsuki et al (2013), sawah ecotechnology involves four important skills and technologies:

(1) Site selection and site-specific sawah system design,

(2) Skills for efficient and cost-effective sawah system development using power tiller,

(3) Rice farmers' socio-economic empowerment for the successful development and management of sawah systems, and

(4) Sawah-based rice agronomy, including variety selection and soil and water management to realize at least the sustainable paddy yield of more than 4t/ha.

As against Sawah systems in Asia and Japan - developed using hundreds and thousands of years with manual labour of farmers using classic and traditional technology - sawah technology developed in Nigeria has unique characters of using power tiller (and may be wetland tractor soon in future). This is an INNOVATION to accelerate irrigated sawah development by farmers' power themselves in Africa. The sawah technology innovation is unique in terms of development cost (less than 10% compared to contractor based heavy machine used development), speed (1million ha can be developed within decades with proper dissemination systems), and endogenous sustainable development (on-the-job capacity building of million farmers).

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 1986 (Hirose and Wakatsuki 2002). On-farm adaptive research and participatory trials on Sawah system research were conducted on the research sites for four years (1986–1990) by Japanese researchers. In partnership with Watershed Initiative in Nigeria, a Non Governmental Organization (NGO), Agricultural Development Project (ADP), Ministry of Agriculture, Niger state and National Cereals Research Institute (NCRI), the dissemination of the sawah technology took off in 2001 from villages previously identified in a diagnostic survey (Oladele and Wakatsuki 2010). Since then, the dissemination and adoption have continued in other parts of Nigeria.

1.12. Sawah Hypotheses

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

The sawah ecotechnology is the prerequisite platform condition for applying the three Green Revolution technologies (Sawah hypothesis 1). The rice GR includes three core technologies – (1) irrigation and drainage, (2) fertilizers and agrochemicals, and (3) the use of HYVs. Although these three technologies have been available for the past 40 years, they have not been effective in farmers' fields in SSA. In order to apply these scientific technologies, farmers' fields must develop sawah or other similar alternatives, typically in the lowlands that can conserve soil and control water, Sawah hypothesis 1. Irrigation without sawah farming technology has proved inefficient or even damaging because of accelerated erosion and waste of water resources. In the absence of water control, fertilizers cannot be efficiently used. Therefore, the high yielding varieties perform poorly and soil fertility cannot be sustained, hence GR cannot take place. Essential components with regard to land development are (1) demarcation by bunding based on topography, hydrology, and soils, (2) levelling and puddling to control water and weeds and conserve soil, and (3) water inlets to get water (using various irrigation facilities) and water outlets to drain excess water. These are the characteristics of sawah fields.

Sawah Hypothesis (II) for Intensive Long-term Sustainability and to Combat Global Warming

Sawah technology ensures an intensive long –term sustainability of rice production. Lowland sawah systems can sustainably produce paddies at approximately 2 t/ha without any chemical fertilizer application (Hirose and Wakatsuki 2002, Wakatsuki et al. 2009). Furthermore, lowland sawah systems can support rice cultivation continuously for decades, centuries, or more without any fallow period as against upland slash-and-burn rice fields which hardly sustain paddy yields in excess of 1 t/ha without fertilizer. Upland paddy fields require a fallow period to restore soil fertility, typically 2 years of cultivation and 8 or sometimes more than 15 years of fallow. This means that 1 ha of sustainable upland rice cultivation requires at least additional 5 ha of land. Therefore, the sustainable upland paddy yield is actually not 1 t/ha but less than 0.2 t/ha. In all, the sustainable productivity of sawah-based rice farming is more than 10 times higher than that of the upland slash-and-burn rice method (Sawah Hypothesis 2). It is known to be true based on the long history and experience (not experiments) of sawah-based rice farming in Asia, although no scientific or quantitative confirmation exists yet. We therefore must quantitatively determine the sustainable yields under SSA conditions (Wakatsuki, 2013). It is known that the development of 1ha 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 increase food production but also to forest conservation, which in turn enhances the sustainability of intensive lowland sawah systems through nutrient cycling and geological fertilization processes (Wakatsuki, et al., 2013).

Sawah and traditional rice side by side in Zaria Nigeria. Traditional rice is characterised by poor tillering and weeds. (Photo from Prof Wakatsuki)

1.13. Adoption of Agricultural Technology

The use of improved technologies in form of innovations has remained the major strategy used to increase agricultural productivity and promote food and livelihood security among people. Innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption (Rogers, 2003). Adoption process is the mental process an individual passes through from first hearing about an innovation to final adoption (Rogers, 2003). For an innovation to be adopted, it must pass through a process of diffusion. Diffusion is the process in which an innovation is communicated through certain channels over time among the members of a social system (Rogers, 2003). Rogers (2003) identifies five attributes upon which determine the adoption of an innovation. These are relative advantage, compatibility, complexity, triability and observability. Relative advantage refers to the degree to which an innovation is perceived as better than the practice it replaces. Relative advantage is often expressed in terms of economic, social or other benefits. Compatibility refers to the degree to which an innovation is perceived by potential adopters to be consistent with their existing values or practices. Compatibility with what is already in place makes the new practice seem less uncertain, more familiar and easier to adopt. Complexity refers to the degree to which an innovation is considered as difficult to understand and use. If potential adopters perceive an innovation as complex, its adoption rate is low. Triability refers to the extent to which an innovation may be subjected to limited experimentation. Finally, observability refers to the degree to which the results of an innovation are visible to others.

Adoption of an innovation involves five stages according to Rogers (2003). These are Knowledge, Persuasion, Decision, Implementation and Confirmation. Knowledge occurs when an individual is exposed to an innovation's existence and gain an understanding of how it functions. Persuasion occurs when an individual forms a favourable or unfavourable attitude towards the innovation. Decision takes place when an individual engages in activities that lead to a choice to adopt or reject the innovation. Implementation occurs an individual puts a new idea into use. Confirmation takes place when an individual seeks reinforcement of an innovation-decision already made, but he or she may reverse this previous decision if exposed to conflicting messages about the innovation.

1.14. Adopter Categories

Individuals in a social system do not all adopt an innovation at the same time but rather in an over-time sequence (Rogers, 2003). Individual adopter can therefore be categorised on the basis of when they begin using a new idea. Based on the time an individual adopts an innovation, Rogers (2003) categorised adopters into innovators, early adopters, early majority, late majority and laggards. Innovators are the first individuals to adopt an innovation. Innovators are willing to take risks, youngest in age, have the highest social class, have great financial lucidity, very social and have closest contact to scientific sources and interaction with other innovators. Risk tolerance has them adopting technologies which may ultimately fail. Financial resources help absorb these failures. Early adopters are the second fastest category of individuals who adopt an innovation. These individuals have the highest degree of opinion leadership among the other adopter categories. Early adopters are typically younger in age, have a higher social status, have more financial lucidity, advanced education, and are more socially forward than late adopters. They are more discrete in adoption choices than innovators. Realize judicious choice of adoption will help them maintain central communication position Early Majority adopt an innovation after a varying degree of time. This time of adoption is significantly longer than the innovators and early adopters. Early Majority tend to be slower in the adoption process, have above average social status, contact with early adopters, and seldom hold positions of opinion leadership in a system. Late Majority will adopt an innovation after the average member of the society. These individuals approach an innovation with a high degree of skepticism and after the majority of society has adopted the innovation. Late Majority are typically skeptical about an innovation, have below average social status, very little financial lucidity, in contact with others in late majority and early majority, very little opinion leadership. Laggards are the last to adopt an innovation. Unlike some of the previous categories, individuals in this category show little to no opinion leadership. These individuals typically have an aversion to change-agents and tend to be advanced in age. Laggards typically tend to be focused on "traditions", likely to have lowest social status, lowest financial fluidity, be oldest of all other adopters, in contact with only family and close friends, very little to no opinion leadership.

1.15. Sawah Road Map and Justification for this study

For sawah to achieve the much anticipated Green Revolution (GR) in Nigeria, a road map was drawn by Prof (Emeritus) Toshiyuki Wakatsuki-the leader of sawah team in Africa. This road map outlines the stages sawah will take to achieve self-sufficiency in rice production not only in Nigeria but other countries in Sub Saharan Africa (SSA). The road map is in six stages. **Stage 1** spanned between 1986 and 2002. It covered 10 sites, 6ha of sawah and 17 years of trials and errors. It involved basic research to investigate the possibility of sawah development. **Stage 2** spanned between 2003 and 2007. It covered 20 sites, 30ha benchmark sites. It involved action research to investigate the expansion of applicability. **Stage 3** spanned between 2007 and 2011 and covered 100 sites, with more than 200ha with establishment of 4 sawah technology components. It also involved large-scale action research and On-the-Job training for full scale dissemination. **Stage 4** will be between 2012 and 2016 and will cover more than 500 sites, more than 2500ha of sawah in Nigeria and Ghana. It has immediate target to reform the traditional official development assistance (ODA) approach. **Stage 5** will be between 2017 and 2022 and will cover more than 2500 sites, more than 25,000ha of sawah. This will be Africa wide adaptation and dissemination and endogenous sawah technology development. **Stage 6** will be between 2022 and 2026 with more than 20000 sites, more than 200,000ha of sawah. This will be African wide spontaneous and rapid sawah expansion for the achievement of GR.

With the completion of stages 1, 2 and 3, there is therefore a need to evaluate the development of sawah technology in Nigeria to chart a way forward for the attainment of stages 4 to 6. In doing this, there is therefore a need to carry out both socio-economic and soil analytical survey. This study will identify the successes achieved and the areas for improvement. It will help in dissemination of sawah technology to other areas where sawah is yet to be adopted. This study therefore aimed at evaluating the socio-economic factors affecting the adoption and dissemination of sawah technology in Nigeria. This study will also investigate the fertility status of sawah soils in Nigeria.

1.16. Objectives of the study

The objectives of this study are to:

2. Identify the factors affecting the adoption of sawah technology in Nigeria
3. Determine the effect of land tenure on the adoption of sawah technology
4. Identify the major constraints to adoption of sawah technology
5. Identify the roles of training in adoption of sawah technology
6. Investigate the physico-chemical and geochemical status of the sawah soils in Nigeria.

1.17. Experience from Ghana sawah development

Sawah technology was introduced to farmers in Ahafo Ano South district of Ashanti region of Ghana in 1998 through a collaboration of the Council for Scientific and Industrial Research (CSIR) and Japan International Co-operation Agency (JICA) joint study project. Yield of rice increased from 1.0 t ha^{-1} under traditional system to over 5.0 t ha^{-1} using sawah under farmers' condition within four years. Sawah in Ghana proved to be a better option or alternative to traditional system of rice production.

This study evaluated the factors responsible for the adoption of sawah technology in Ghana with a view of applying same in Nigeria to increase rice production. This study further investigated the degree of soil degradation in Ghana with a decade of adoption of sawah technology with a view of adopting measures aimed at preventing soil degradation in Nigeria as a result of sawah adoption.

The study therefore

1. Identified the determinants of adoption of sawah technology among farmers in Ashanti region of Ghana.
2. It also examined the changes that have occurred in soil chemical parameters along topo-sequence in the watershed of Ashanti region between 2000 and 2011.

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CHAPTER 2

Factors Affecting the Adoption of Sawah Technology System of Rice Production in Nigeria.

2.1. Introduction

The food sub-sector of Nigerian agriculture parades a large array of staple crops, due to the variations in the climatic conditions in the country. The food crops include rice, sorghum, maize, millet, rice, wheat, yam, cassava, groundnut, cowpeas and vegetables. Among these food crops, rice is most consumed by many households in Nigeria. Thus, rice has, become a strategic commodity in the Nigerian economy. Rice is an important source of nutrition and one of the major staples which can provide Nigerian population with the nationally required food security (Food and Agriculture Organization (FAO), 2000). An average Nigerian consumes 24.8 kg of rice per year, representing 9 per cent of annual calorie intake (International Rice Research Institute (IRRI), 2001). Nigeria has experienced rapid growth in per capita rice consumption during the last three decades, from 5 kg in the 1960s to 25 kg in the late 1990s (Africa Rice Centre (WARDA), 2003). With this increasing contribution of rice to the per capita calorie consumption of Nigerians, the demand for rice has been increasing at a much faster rate than domestic production and even more than in any other African country since mid 1970s (FAO, 2001).The demand for rice in Nigeria has been soaring. Rising demand was partly the result of increasing population growth, increased income levels, rapid urbanization and associated changes in family occupational structures (Akande, 2003).

Consequently, the Nigerian government has interfered in the rice sector over the past few decades making effort to increase rice production for local consumption. Although rice production in Nigeria has increased during this period but the production increase was insufficient to match the consumption increase with rice imports making up the gap (Erenstein et al., 2003). The need to increase local production necessitated the introduction of sawah technology to enhance domestic production. Sawah refers to man-made improved rice fields with demarcated, levelled, bunded and puddled rice fields with water inlets and outlets which can be connected to various irrigation facilities such as irrigation canals, pond, springs or pumps. The term sawah originated from malayo – Indonesia. The English and French terms, paddy or paddi also originated from Malayo Indonesian term padi which means rice plant. Therefore in order to avoid confusion between upland paddy fields, and man-made levelled , bunded and puddled rice field that is, typically irrigated rice growing environment the authors propose to use the term "sawah" in SSA (Wakatsuki and Buri, 2008). Sawah-based system of rice production was reported to have contributed to the achievement of green revolution in Asia. The speed and scale with which it solved the food problem was remarkable and unprecedented, and it contributed to a substantial reduction in poverty and the launching of broader economic growth in Asia. With green revolution, per capita production of rice has increased from 200kg to more than 250kg in the last 40 years in Asia (Wakatsuki and Buri, 2008). It can overcome soil fertility problems through enhancing geological fertilization process, conserves water resources, and high performance multi-functionality are characteristics of the sawah type wetlands (Oladele and Wakatsuki, 2008). Therefore, with its inherent potential, there is the need to develop a better understanding of the conditions that encourage its sustained adoption.

2.2. Adoption of Agricultural Technology

Adoption process is the mental process an individual passes through from first hearing about an innovation to final adoption (Rogers, 2003). Technology transfer (or extension in a rural context) involves the movement of technical knowledge, ideas, services, inventions and products from the origin of their development (or other location), to where they can be put into use. Technology adoption is the implementation of this transferred knowledge about an innovation, and is the end product of extension (Rogers, 2003).

Farmers may reject or abandon many technologies that have been proved useful, and adopt others in their place since they consider a variety of factors in deciding whether or not to adopt particular innovation (McDonald and Brown, 2000). Various factors have been considered in adoption studies. For instance, Clearfield & Osgood (1986) considered individual characteristics of farmers (e.g. age, off-farm employment, and social participation) and attitude variables, such as risk orientation, and non-economic orientation towards farming. Others studies focused on farm characteristics (e.g. farm size), wealth indicators (e.g. livestock numbers) and on the availability and profitability of the technology (Doss, 2006). Sall et al. (2000) and Wortman and Kirungu (1999) reported that not only farm and farmers' characteristics, but also farmers' perceptions of technology-specific characteristics significantly influence adoption decisions relating to improved rice varieties.

Focusing primarily on the initial stages of green revolution technology adoption and diffusion, Feder et al. (1985) concluded that farm size, risk and uncertainty, human capital, labour availability, credit constraints, and tenure security were the most important factors determining adoption decisions. Kolawole et al. (2003) reported on Nigerian farmers who abandoned a technology due to natural hazards and emerging economic constraints. Lapar and Ehui (2004) found out that farmers who are more educated, have higher income, and have access to credit are more likely to adopt the innovation. Moreover, location of the farm in respect to the availability of innovation also plays a critical role in adoption. Chi (2008) in a study to determine the factors affecting technology adoption among rice farmers in the Mekong Delta reported that farmers' perception and education, extension workers' knowledge, ways of organization and management of extension programs, and physical conditions of the area influenced adoption among the farmers. Tiamiyu et al. (2009) also reported that technology adoption and productivity difference among growers of New Rice for Africa in savanna zone of Nigeria was affected significantly by farmers' level of education, extension visits, rice farming experience, tenure status, credit use and level of rice commercialization. Farm size, type of ecosystem, tillage type, education, population pressure on land farmers' age and non-farm income were found to be positively and significantly related to adoption and use intensity of chemical fertilizer, while field distance to the village, gender, access to credit and labour availability had an indirect relationship with adoption and use intensity of chemical fertilizer were found to affect Fertilizer adoption by rice farmers in Bende local government area of Abia State, Nigeria (Onyenweaku et al.,2007).

Adesina (1996) found that the major factors that affect farmers' use of fertilizers in rice fields, are cultivation of lowlands, use of mechanization, farm size, type of rice ecosystem, tillage methods, cultivated area, land pressure faced by households, availability of non-farm income, the distance of the field to the village, distance of the village to the major market, and gender of the field owner. Family size, membership in social institutions, rate of participation in extension activities and number of extension contacts were also identified as the socio-personal characteristics affecting the adoption of rice-fish culture system in North of Iran (Niyaki and Allahyari, 2010). Malian et al. (2004) in a study to determine the factors affecting production, consumption and price of rice, and inflation in food sector found that previous paddy harvest, area cultivated , rice import, price of urea-based fertilizer, real exchange value, and domestic rice price influence rice production.

Since sawah technology aims at achieving green revolution in Nigeria through the improvement in rice production, a study of the factors affecting the adoption and continued use of the sawah technology is pertinent. The need to examine the factors affecting the adoption and continued use of the sawah technology is no other time but now. This study therefore aimed at identifying the factors affecting adoption and continuous use of sawah eco-technology system of rice production in Nigeria. Specifically, the study will determine the awareness, level of adoption of sawah eco-technology in Nigeria, reasons for the adoption of sawah system of rice production and the factors affecting the adoption of sawah technology.

2.3. Method

This study was carried out in Nigeria, covering five states and the FCT where sawah is being practiced. The states are Niger, Kaduna, Ondo, Kwara, Ebonyi and Abuja. A list of rice farmers in the villages where sawah technology was disseminated was compiled. One hundred and twenty four farmers in the study locations were interviewed. A structured interview guide was used to elicit information from the farmers. Descriptive statistics were used to analyse the socio-economic and farming characteristics of the farmers and regression analysis was used to determine the relationships between the variables of the study.

The interview guide was divided into five sections. The first section captures the socioeconomic characteristics of the responds. The second section captures the level of awareness and adoption of sawah eco-technology package among the farmers. A 3-point likert scale of Full adoption, partial adoption and discontinued was used. The third section of the data collection captures farmers' reasons for the adoption of sawah technology rice production system. The forth section addresses the factors affecting the adoption of sawah eco-technology rice production. The last section identifies the constraint faced by the farmers.

Farmers being interviewed during the data collection process.

2.4. Result and Discussion

Socio-economic and farming characteristics of the respondents: Table 1 shows the socio-economic and farm characteristics of the respondents. The majority of the respondents are male (98.9%). This shows that male farmers dominated sawah farming in Nigeria. The mean age of the respondents is 42.30 years and 65.40% fell within the productive age of 15-45 years. Most of the respondents are married (98.80%) and 62.70% of the farmers had Quranic education and are Nupes. These findings agree with the findings of Fu et al. (2009) and Oladele and Wakatsuki (2009). Household size of the farmers ranged between 1 and 40 persons (X = 14). Fifty-five percent of the farmers had between 11 and 20 household size. The advantage of the relatively large household size of the farmers is that the family members could serve as a viable source of farm labour. The mean size of farm devoted to sawah is 0.5ha. However, the majority of the farmers have farm sizes less than 0.5 ha. The mean farmers' income is ₦151,000 ($1041). Mean farmers' years of experience in rice production and sawah production are 32 and 6 years respectively. This implies that the respondents have considerable experience in rice production and hence are capable of using sawah technology. Also, farmers' experience in rice production will be of great importance in developing the skills required for sawah rice production. The mean yield of rice from the sawah field is 2.5 tonnes with majority of the farmers (77.30%) having yield of less than 2 tonnes. The yield corresponds with the size of the field. In all, yield of sawah field among the sawah farmers is 4.65 tonnes per hectare. The average distance covered from the farmers' house to the farm is 0.7km. Also, 33.80% of the farmers have access to extension services but 85.00% have access to a trained contact farmer in sawah technology. Majority of the farmers (97.50%) are members of farmers' organization and used members of their family as their labour source (53.80%).

Table 1: Socio-economic and farming characteristics of the respondents (N=124)

Characteristics	Percentage	Mean
Sex		
Male	98.9	
Female	1.10	
Age		
15-30	22.00	
31-45	43.40	42.30
46-60	20.10	
Greater than 60	14.50	
Marital status		
Married	98.8	
Single	1.20	
Educational level		
Quranic	62.70	
No formal education	3.60	
Primary	12.00	
Secondary	18.10	
Tertiary	3.60	

Household size		
1-10	31.10	
11-20	55.60	14
21-30	9.70	
31-40	3.60	
Farm size(ha)		
Less than 0.50	73.90	
0.50-1.00	17.00	0.53
Greater than1.00	9.10	
Income(₦)		
<100,000	18.10	
100,000-200,000	57.80	151,110
>200,000	24.10	
Yield of sawah rice		
0-2 tonnes	77.30	
2.1-4.0 tonnes	14.70	2.5 tonnes
4.1-6.0 tonnes	2.30	
Greater than 6.0 tonnes	8.00	
Access to extension services	33.80	
Access to contact farmer	85.00	
Membership of farmers organization	97.50	
Labour use		
Family	53.80	
Hired	46.20	

Awareness and Adoption among the Respondents: Table 2 shows the level of awareness and adoption of sawah technology among the farmers. There was a high awareness of puddling (98.80%), bunding of field (100.00%), power tiller use (95.00%), the use of sand bags (92.50%), flooding and flood control (88.80%) and nursery preparation (87.50%). The high level of awareness has influence on the level of adoption among the farmers. Sawah technology package has 56.25% full adoption, 30.55% partial adoption and 13.20% discontinued use of sawah technology. This implies that there is high adoption of sawah technology among the farmer. This may be due to high yield from sawah field, the improvement in the rate of tillering of the rice, efficiency of fertilizer usage and effective weeds control (Fashola et al., 2006). The high level of adoption among the farmers is a direction toward achieving green revolution in Nigeria. There is a high adoption of bunding

(100%), canal construction (100%), use of nursery (95%), power tiller use (95%), and puddling (91.20%), use of sand bag (80%), flooding/irrigation (76.2%), levelling (72.5%) and smoothening (67.5%) respectively. It could be deduced from the results that awareness of innovation has a great influence on the adoption. Adoption process is the mental process an individual passes from first hearing (awareness) about an innovation to final adoption (Rogers, 2003). However, the level of the discontinuity among the farmers based on findings was due to the non availability of the required inputs such as power tiller for puddling. As reported by Ademiluyi et al. (2008), power tiller is the only power-driven tool that is effectively being used for sawah activities in Nigeria and a set of power tiller cost 5000-7000 USD which an average farmer cannot afford to buy. Difficulty of transplanting of rice seedlings and the required labour for the transplanting, difficulty faced in water management and distribution which sometimes result in flooding of fields, and inability to expand the size of their farm due to land tenure constraint are other factors responsible for the discontinuity. Discussion with the farmers revealed that they are willing to continue the adoption if these problems are solved.

Table 2: Awareness and Level of adoption of sawah ecotechnology package (N=124)

Innovation package	Awareness (%)	Full Adoption (%)	Partial Adoption (%)	Discontinued
Puddling	123(98.80)	71(57.50)	42(33.80)	11(8.80)
flooding/irrigation	110(88.80)	71(45.00)	39(31.20)	30(23.80)
Levelling	109(87.50)	30(23.80)	61(48.80)	34(27.50)
Smoothening	104(83.80)	25(20.00)	59(47.50)	40(32.50)

Nursery	109(87.50)	96(77.50)	22(17.50)	6(5.00)
Power tiller use	118(95.00)	40(32.50)	78(62.50)	6(5.00)
Dyke construction	25(20.00)	0(0.00)	19(15.00)	105(85.00)
Bund construction	124(100.00)	105(85.00)	19(15.00)	0(0.00)
Agro forestry and sawah production	0(0.00)	0(0.00)	0(0.00)	124(100.00)
Canal construction	92(73.80)	84(68.00)	40(32.00)	0(0.00)
Use of sand bags	115(92.50)	34(27.50)	65(52.50)	25(20.00)
Total score	-	**1625**	**882**	**381**
Percentage	-	**56.25**	**30.55**	**13.20**

Reason for Adoption of Sawah Technology: Table 3 shows the reasons and motivating characteristics of sawah technology that facilitated adoption among the farmers. All the farmers adopted sawah technology because of the high yield from sawah field (100.00%).

High yield is a factor that motivated farmers to adopt sawah technology.

Majority of the farmers adopted sawah technology because of the improvement in the rate of tillering of the rice (90.00%) and efficiency of fertilizer usage (75.00%). Adoption of sawah technology among the farmers was also facilitated by the rate at which the weeds are been controlled (87.50%). In a well laid out field, with proper water control, throughout the growing season, weeding may not be necessary. Other factors motivating the farmers to adopt sawah were ease of diseases and pest management, water management and land preparation. This result agrees with the finding of Fu et al. (2009), who reported that higher yield, better water and weed control are the major reasons why Nupe farmers adopted sawah technology.

Table 3: Reasons for the adoption of sawah ecotechnology rice production (N=124)

Reasons	**Percentage**
High yield	100.00
Ease of disease management	72.50
Ease of pest management	70.00
Fertilizer management	75.00
Weed control	76.20
Water management	87.50
Land preparation	68.80
Good tillering	90.00

Factors affecting Adoption of Sawah Technology: Table 4 shows the factors affecting the adoption of sawah technology among the farmers. These factors are attributes of the sawah technology, attitude of farmers toward sawah technology, the availability of necessary inputs and communication factor. Majority of the farmers' perceived usefulness (86.20%) and the ease of use of sawah (85.00%) affected their adoption sawah technology. The fear and anxiety such as crop failure, and risk and uncertainty of the technology did not affect the rate of adoption of the technology. The degree of risk associated with a new technology is another factor that affects farmers' adoption of an innovation. Technologies which are perceived as relatively risky will be less likely to be adopted by farmers. FAO (2001) reported that perceived risk of adopting the technologies may serve as a barrier. Farmers were convinced that sawah technology can help achieve their goal of increase productivity.

The increase in yield (83.80%) of sawah rice made them to adopt the technology. Agricultural innovations that are believed to be profitable to the farmers have an increased likelihood of adoption. On the other hand, if a farmer does not feel that an innovation will be of benefit, there may not adoption in such instance (Vanslembrouck et al., 2002). The ease of diseases and pest control (63.00%) associated with sawah technology as reported by this study made farmers to adopt the technology. Effectiveness of weed control (68.80%) of sawah technology and effective water management (70.50%) of sawah technology as reflected in this study made the farmers to adopt the innovation. In a well laid out and levelled sawah field, with proper water distribution, the farmer may not need to weed throughout the growing season and there will be effective fertilizer distribution and usage. Fertilizer management (70.50%) in sawah technology made the farmers to adopt the sawah technology. Sawah system encouraged the growth of various aquatic algae and other aerobic and anaerobic microbes in addition to rice growth, which increase nitrogen fixation in the sawah system through increase of photosynthesis as functional wetlands. The amounts of nitrogen fixation under the submerged sawah systems are not well evaluated, the amounts could be 20-100kg/ha/year in Japan and 20-200kg/ha/y in tropics depending on the level of soil fertility and water management (Kyuma 2004; Greenland 1997). Fu et al. (2009) also reported that higher yield, better water and weed control, have been recognized by participating farmers as the factors affecting the adoption of sawah technology among the Nupe farmers.

However, access to credit, extension, market and input availability do not influence the adoption of sawah technology among the farmers. Most of these resources farmers do not have access to and hinder the rate at which farmers increase their level of production. Communication factor identified to be affecting the adoption of sawah technology among the farmers are access to extension (33.00%), access to contact farmers (70.00%) and feedback problem (2.00%). Access to contact farmers at the door step of the farmers has a greater influence on the rate of their adoption.

Table 4: Factors affecting the adoption of sawah technology (N=124)

Factors	Percentages
Attitude of respondents	
perceived usefulness,	86.20
perceived ease of use	85.00
Fear and anxiety of crop failure	6.50
Perceived risk and uncertainty	2.50
Attributes of Sawah Technology	
Increased yield	83.80
Weed control Ability	68.80
Disease and pest management Attribute	63.50
Effective Water management	70.50
Fertilizer management efficiency	70.50
Facilities and resources	
Access to credit	12.50
Access to market	38.80
Availability of input	8.80
Communication and Extension	
Access to Extension Agent	18.20
Access to Contact farmer	70.00
Feedback problem	2.00

Regression Analysis between adoption level and other study variables: Table 6 shows the result of regression analysis to determine the relationship between adoption of sawah technology and factors affecting adoption. The result shows that adoption of sawah technology is related to awareness ($\beta=0.80$; $p<0.01$). This implies that the higher the level of awareness, the higher the level of adoption. Also attitude of farmers is significantly related to their level of adoption ($\beta=0.48$; $p<0.01$). Due to the benefit derive from sawah, farmers have positive attitude towards sawah technology. The yield of sawah farmers has increased from 1.4 tonnes per hectare (WARDA, 1999) to 4.6 tonnes per hectare as a result of the adoption of sawah technology. Also the attributes of sawah technology ($\beta=0.33$; $p<0.01$) which include high yield from sawah field, improvement in the rate of tillering of the rice, efficiency of fertilizer usage, weeds control, ease of pest management and water management and the relative ease of adoption. Access to contact farmers ($\beta=-0.51$; $p<0.01$) was also significantly related to adoption. Contact farmers were trained in all the sawah locations in Nigeria to serve as link between the source of technology and the farmers. The result shows that household size of the farmers ($\beta=0.25$; $p<0.05$) was related to the adoption of sawah technology. This implies that the larger the size of the family, the higher the level of adoption. This may be true because when the size of the family increases, farmers may tend to increase the size of his farm. In addition, large size of the family could serve as a source of labour hence affects the level of adoption. This also agrees with the findings of Adesoji, et al. (2006) which reported that large household size increased farmers' participation in farm activities. Also, a significant relationship exists between adoption and constraint faced by farmers ($\beta=-0.32$; $p<0.02$). This implies that the higher the constraints faced by farmers the lower the rate of adoption. Adoption of sawah technology depends on the availability of power tillers, fertilizers, improved rice seeds and other farm inputs. Availability of this input will influence the level of adoption of sawah technology among the farmers. The more available farm inputs are the greater the level of adoption and expansion of sawah technology. The age of the farmers ($\beta=-0.44$; $p<0.01$) negatively related to level of adoption. This could be because of resistance to change by aged farmers (Adesoji, et al (2006); Ajayi, (1995). Older farmers find it difficult to change from their former way of doing thing for a new method. The younger farmers may be inquisitive, wanting to learn more, hence increase their level of adoption. The results of the regression analysis were also supported by the findings of Feder et al. (1985) who reported that farm size, risk and uncertainty, human capital, labour availability, credit constraints, and tenure security were the most important factors determining adoption decisions.

Table 5: Regression analysis between adoption level and other study variables (N=124)

Variables	B	SE	Std β	t-ratio	sig
Constant	3.16	3.20	-	0.99	0.33
Awareness	2.71	0.44	0.80	6.10	0.00
Age	-0.13	0.04	-0.44	-3.22	0.00
Experience in sawah	2.69	1.48	0.13	1.82	0.07
Access to contact farmer	3.84	0.55	0.51	6.98	0.00
Attitude of farmer	7.06	1.42	0.48	4.95	0.00
Attributes of the Sawah technology	2.89	0.78	0.33	3.70	0.00
Access to extension services	1.07	0.62	-0.13	-1.73	0.09
Constraints faced by farmers	-3.70	1.52	-0.32	-2.44	0.02
Household size	0.14	0.05	0.25	2.86	0.01
Experience in rice production	0.04	0.03	0.16	1.23	0.23
Communication	-1.34	1.35	-0.10	-1.00	0.32

R=0.89, R^2=0.79, Adjusted R^2= 0.76, F= 21.36, Standard Error of Estimate= 2.01.

2.5. Conclusion

Based on the findings of this study, it was concluded that awareness of sawah technology was high among the farmers and influenced their adoption of sawah technology. High yield from sawah, good tillering, water management, fertilizer management and weed control and other characteristics of sawah technology were the major reasons why farmers adopted sawah technology. Adoption of sawah technology was influenced positively by awareness, attitude of farmers, attributes of sawah technology, access to contact farmers and household size and negatively influenced by age of farmers and the constraints faced by farmers. The adoption is however faced with some constraints. The study recommends that constraints faced by farmers should be addressed urgently to enhance the achievement of green revolution in Nigeria through sawah technology.

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CHAPTER 3

Effect of Land Tenure on Adoption of Sawah Rice Production System in Nigeria.

3.1. Introduction

Nigeria is the most populous country in Africa, with a population of over 140 million people and is the largest rice producer. Agriculture accounts for about 40 percent of the Gross Domestic Product (GDP) and 70 percent of the labour force (Information Technology Associates (ITA), 2011). Agriculture is the main source of food for most of the population. It provides the means of livelihood for over 70 percent of the population, a major source of raw materials for the agro-allied industries and a potent source of foreign exchange (World Bank, 1998; Okumadewa, 1997).

Land as an important factor in agricultural production plays a critical role in the livelihood systems of farmers. The relationship between land and the people is profound. People's standard of living, wealth, social status and aspirations are all closely linked to land and may be determined by access to land. Place (2009) described land as factor that promotes or inhibits agricultural investment. The vital role land plays in sustaining life for human beings has led societies to establish arrangements concerning the ownership and use of land, usually referred to as land tenure. Land tenure involves the rules and procedures governing the rights, duties, liberties, and exposure of individuals and groups in the use and control over such basic resources as land and water (Matlon, 1994).

The study of tenure and its effects on agricultural productivity is not new, but is particularly challenging given that many different types of land tenure systems are in existence. Land tenure system is commonly cited as a key constraint, sometimes the key constraint to agricultural intensification and rural development (Smucker, 1981). It has an essential role to play in increasing as well as sustaining agricultural production. The extent to which this role is performed is determined in part by methods of land acquisition and arrangements for the ownership and use of land. Land is the most significant tangible asset and serves as a powerful fulcrum for access to labour and capital resources. The most common land tenure system found in Sub-Saharan Africa (SSA) is community-based ownership of land where individuals belonging to a particular community have access and use rights to land which is held in trust by the community. The modes through which individuals have access to land in West Africa include inheritance, gift, purchase, rent, pledge, and sharecropping (Lawry *et al.*, 1994).

In the literature, there are divergent views on the importance of tenurial arrangement as it affects adoption decisions. Empirical studies have reported mixed findings on the impact of formal land titles on investment and agricultural productivity. The World Bank (2003) reported that studies in Africa show that formal land title had little or no impact on investment or farm income, partly due to the fact that land is usually secured under most customary land rights and formal land titles do not necessarily equal to higher tenure security**.** Gavian and Ehui (1999) found no empirical evidence that land tenure is a constraint to agricultural productivity. In China, the right to use a parcel land for long period of time encouraged the use of land-saving investments and land tenure affected agricultural production decisions although the difference between collective and private plots was small (Li et al., 1998). However, Chirwa (2006) showed that access to larger parcels of land was associated with commercialisation of food crops. Therefore, land redistribution under conditions of functioning factor and product markets holds the potential for delivering tangible benefits to household welfare.

3.2. Sawah Technology in Nigeria

In Nigeria, rice is cultivated under three systems, which are rainfed upland, irrigated, and rainfed lowland conditions (Oladele and Wakatsuki 2010a). Production under upland and irrigated conditions according to Oladele and Wakatsuki (2010a) has not been able to meet the production needs in Nigeria. Inland valleys scattered across the country may offer the best rice ecology with proper water control and management (Oladele and Wakatsuki 2010a). Sawah rice production system was introduced to the inland valley of Nigeria because it can overcome soil fertility problems through enhancing the geological fertilization process, conserving water resources, and the high performance multi-functionality of the sawah type wetlands (Oladele and Wakatsuki 2008). Sawah system encouraged the growth of various aquatic algae and other aerobic and anaerobic microbes, which increase nitrogen fixation in the sawah system through increase in photosynthesis as functional wetlands (Wakatsuki, 2008).

Sawah-based rice production took off through the establishment of a demonstration farm (1.5 ha) at Ejeti village in Bida, Niger State in 2001 by Japanese researchers in collaboration with Watershed Initiative-a non-governmental organization, Niger State Agricultural Development Programme, Niger state Ministry of Agriculture and National Cereal Research Institute (NCRI) Badeggi, Niger State (Oladele and Wakatsuki, 2008).

Sawah refers to levelled rice field surrounded by banks with inlet and outlet for irrigation and drainage. The basic elements of sawah system include improved irrigated rice basins, seedbed preparation, transplanting and spacing of seedlings, fertilizer application and most importantly, appropriate water management

The successful adoption and utilization of any technology by farmers will definitely depend on the availability of land (with adequate security) needed for its adoption. There is widespread belief that material poverty and insecure land tenure lead to short term planning horizons that do not take investments for a more sustainable land use into account. Since sawah aims at achieving green revolution in Africa, it is important to investigate factors that can limit its objectives. It is therefore of great importance to carry out a study on land tenure systems and its effects on sawah development for sustainable rice production. This study aims to describe the existing land tenure systems in Nigeria and analyze its effects on the adoption of sawah rice production system. The specific objectives of the study are to: (a) determine the level of adoption of sawah technology among the respondents; (b) identify the various tenure systems for assessing land by sawah farmers and their effects on sawah adoption.

3.3. Methodology

Data Analysis: Descriptive statistics were used to analyze the personal and farming characteristics of the farmers. Regression analysis was used to determine effect of the different land tenure systems on adoption of sawah technology. The identified land tenure systems include inheritance, gift, own, rentals and sharecropping. The regression equation is below:

$$Y = a + \beta X_1 + \beta X_2 + \beta X_3 + \beta X_4 + \beta X_5$$

Where

Y = Adoption

X_1 = Inheritance

X_2 = Gift

X_3 = Own

X_4 = Rentals

X_5 = Sharecropping

3.4. Result and Discussion

Land Tenure System: Generally, land tenure system in the study area differs based on tribal inclination. Among the Yorubas (in the South-Western Nigeria), individual ownership of land is common. After allocation is made, communities and families no longer exercise use and management control over farmlands. Family land is divided among all the male members of the family (Adedipe *et al*., 1997). Under this land tenure system, when a man dies, his land will be divided equally among wives having male children. The land is not inherited by the wives directly, but rather by the sons of the wives. Problems often arise between a wife having several sons and another having only one son because of the unequal distribution of land. However, women have no right to secure land as individuals. It is believed that women's portion of land will be secured in their husband's house. For non-members, securing access to land may be restricted to tenancy agreements which may affect their profit from the land (Olayide, 1980).

The most common mode of land acquisition among the Igbos (South-East) is through inheritance. Acquisition through gift and borrowing are less common. In a typical community, the right to inherit land is the major form of social security. Land acquisition by inheritance is usually patrilineal (Arau and Okorji, 1998). The size of land inherited depends on position in the family and the number of wives and brothers. In monogamous families, the eldest son (called *Okpara*) has a preferential allocation of residential plot, and inherits his father's home as the new family head. In rare cases, a system of primogeniture is adopted whereby only the eldest son inherits. If there is no son, the deceased man's wife holds the land in trust until she dies, when it is inherited by the man's younger brother. A man's personal land, family land and common land are all inheritable. Women cannot own or inherit land under customary law, although they retain use rights during their lifetime as long as they remain in the husband's household (Arua, 1978). The Nupe's tenurial system is based predominantly on inheritance (Fu et al., 2009). Most of the farmers transfer their land from one generation to another. The father divides his portion of the family land to all the male children.

The result of the study as shown in Table 1 revealed that inheritance is the dominant tenurial arrangement for accessing land among the sawah farmers. This result agrees with the findings of Fu et al. (2009) and Oladele and Wakatsuki (2009). However other farmers obtained land for sawah by rentals and in turn pay $83 on every hectare of land used in a year and others give 5% of their yield to the land owners in case of sharecropping. In special cases tenants paid the rent before the use of land and also gave part of their yield to the land owners. Discussions with respondents showed that land owners released land to prospective tenants based on ethnic considerations. Land owners preferred to give land to farmers from the same ethnic group but some time to other ethnic groups based on their social relationship and social status. It was also found that due to the increase in the adoption rate of sawah technology, farmers migrated from their communities to other communities in search for lowlands for production. Land is granted by the family head to all members of the family. It was also revealed through personal discussions with the respondents that land right practiced in the study area is majorly the right to use. Every member of the family and the tenant has right to use the family land allocated to him. However, only family members have the transfer right over the family land. Land right may be alienated with the permission and agreement of family head in consultation with other family members.

Result of Regression Analysis between Adoption and Land tenure systems

Table 1 shows the result of regression analysis to determine the relationship between adoption of sawah technology and land tenure systems. The result shows that that there is a significant relationship between adoption of sawah technology and land tenure by inheritance ($\beta=0.871$; $p<0.00$). The result also shows that there is a significant relationship between adoption of sawah technology and own land tenure system ($\beta=0.123$; $p<0.05$). The implication of this result is that secured land tenure system has significant influence on adoption of sawah technology by the farmers. As literature suggests, increased security of tenure in productive resources leads to an enhanced and sustainable agricultural production (Maxwell and Wiebe, 1998; von Maltitz and Evans, 1999).

The result further reveals that there is no significant relationship between adoption of sawah technology and land tenure by gift, rentals and sharecropping. This implies that insecure tenure is a constraint to adoption sawah technology. This is because the land owner reserves the right to increase the rent on the land, review the conditions of the rent to the disadvantage of the tenant or outright take-over of land from the tenant. Under rental system, one is not sure of reaping the benefits of investment in sawah farm because they accrue over time. With rented land, the owner may take over his land, in most cases after one season or two (as confirmed in the course of this study) which does not make it worthwhile for the person who rented land to make long term investments like sawah. Farmers sharing or renting land are less likely to plan for the long term (Clay *et al,* 1994). It must be noted that sharecropping is similar to renting, except that payment is made in kind based on crop production.

The implication of the result of this study is that land tenure security influenced the adoption of sawah technology. Land tenure security determines whether people will invest in and adopt sawah technology and can therefore be regarded as an important ingredient in adoption of sawah technology. This may not be far from the fact that land for sawah development must be secured for a long period of time to accommodate the construction of structures like bund, canals, dykes and other irrigation channels - the main components of sawah technology. Pagiola (1994) found out that it takes about 48 years for a farmer to break-even once soil conservation structures are constructed. Investments into soil conservation measures can only be undertaken with secure tenure especially with regard to soil conservation that has a long gestation period as in the case of sawah technology. Sakurai (2005) reported that investment in water supply canals is influenced by land tenure security and that the canals constructed on sawah fields enhanced yield. Without secure land rights, investment and the up-take of sawah technology will be undermined. The International Land Coalition (2010) described access to secure rights over land as a basic safety net and a political, social and cultural asset. IFPRI (2008) also reported that secured land tenure is an important institutional factor affecting agricultural technology utilization by smallholder farmers by providing incentives for greater investment to enhance the productivity of the land. Access to secured land is a key factor affecting the intensity of land management, the use of higher-yielding agricultural technologies, the profitability of agricultural enterprises (IFPRI, 2008).

Table 1: Result of Regression Analysis between Adoption and Land tenure systems (N =124)

Variables	*Percentage	Standardised coefficients *(β)*	Sign
Inheritance	71.77	0.871	0.00
Gift	2.10	0.041	0.45
Own	12.10	0.123	0.02
Rentals	33.87	0.018	0.69
Sharecropping	1.61	0.019	0.67
Constant			0.00

R = 0.880
R^2 = 0.775
Adjusted R^2 = 0.765
F Change =77.751

*Multiple responses provided**;** Source: Field survey (2010)

3.5. Conclusion and Recommendations

The study on the effect of land tenure on the adoption of sawah technology is important in the quest to achieve Green Revolution in Nigeria. Land as an important factor of production needs to be secured due to the critical role it plays in adoption. Emanating from this study is the fact that land tenure arrangements significantly affect the adoption of sawah technology by farmers in Nigeria. Security of land determined the level of adoption of sawah technology among the farmers. Ensuring high levels of tenure security is important for sustainable adoption of sawah technology. Success of sawah technology based on the findings of this study centres on land availability to the farmers with long-term security. The likelihood for farmers to make medium to long term land improvement investments tends to be high if their tenure is secured, they will be more likely to benefit from whatever investment they might go into. Hence, there is an urgent need for intervention to resolve the land tenure related problems to enhance the achievement of Green Revolution in Nigeria. The study recommends for a reform on land by the government with appropriate legislation and also put in place policies that will ensure effective, simplified, sustainable and successful land administration in Nigeria and give access and security on land for farmer willing to use land for agriculture especially sawah development. This reform should ensure equitable and socially just access to land and ensure security of tenure for all forms of landholdings including both land owners and tenants on rentals. The policies and reforms should also ensure equity irrespective of class, gender, race, ethnicity of the farmers. Land reform is certainly needed to creating an enabling environment that will enhanced tenure security and agricultural intensification as the result of the study has shown that land tenure systems with security influence the adoption of sawah technology among the farmers.

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CHAPTER 4

Land Rights and Rental Systems: Implications for Management of Conflicts Related to Land in Sawah-Based Rice Production Systems in Nigeria

4.1. Introduction

Due to the diversity of the agro-ecological production systems in Nigeria, the food sector of Nigerian agriculture includes a large array of staple crops. Among these crops, rice has risen to a position of greatest importance. As far back as the mid-1970s, rice consumption in Nigeria was increasing tremendously, at about 10% per annum, due to changing consumer preferences and increases in the population. Domestic production has never been able to meet the demand, leading to considerable imports, which, as of 2011, accounted for about 1,000,000 metric tonnes yearly, with Nigeria spending more than US$300 million on rice imports annually. The demand for rice has been increasing at a much faster rate in Nigeria than in other West African countries since the mid-1970s (Food and Agriculture Organization of the United Nations (FAO), 2001). According to the FAO (2001), Nigeria had the lowest per-capita annual consumption of rice in the sub-region (average of 3 kg) during the 1960s. Since then, Nigerian per-capita consumption levels have grown significantly, at 7.3% per annum. Consequently, per-capita consumption during the 1980s averaged 18 kg and reached 22 kg in 1995–1999. Average growth rates in Nigerian per-capita rice consumption are likely to continue for years to come.

Rice is cultivated in virtually all the agro-ecological zones in Nigeria. Despite this, Nigeria's rice production capacity is still far below the demand. The average yield of upland and lowland rain-fed rice in Nigeria is 1.8 ton/ha, whereas that of land with irrigation systems is 3.0 ton/ha (PCU, 2002). This is very low when compared with 3.0 ton/ha from upland and lowland systems and 7.0 ton/ha from irrigated land in other countries (WARDA & NISER, 2001). The sawah rice production system was introduced to the inland valley of Nigeria to increase the yield of rice because it can overcome soil fertility problems through geological fertilization processes (Oladele & Wakatsuki, 2008). Sawah refers to a leveled rice field surrounded by banks with inlets and outlets for irrigation and drainage. The basic elements of the sawah system include improved irrigated rice basins, seedbed preparation, transplanting and spacing of seedlings, fertilizer application, and, most importantly, water management. According to Nwite et al. (2011), sawah lowland farming with small-scale irrigation schemes for integrated watershed management constitutes the most promising strategy for addressing soil fertility problems and restoring the degraded watershed in the tropical environment for increased and sustainable food production. The sawah system utilizes the inland valleys, which are reported to be high in fertility, through appropriate water management. According to Nwite et al. (2011), sawah remains the prerequisite technology for restoring and conserving the degraded watershed in the tropical environment for increased and sustainable food production and ultimately in pursuit of the much-awaited Green Revolution (GR) in West Africa.

One of the major constraints faced by sawah rice production in Nigeria is the problem of land tenure (Oladele &Wakatsuki, 2009). Hart (1982) described the land tenure situation in Africa as confusing and conflict-ridden. Constraints relating to insecure land tenure have continued to discourage Africans from making needed agricultural investments (CAPRI, 2005). Secure access and rights to land are fundamental to the achievement of food security and sustainable rural development. Insecure and limited access to land has contributed to poverty, which in turn has provided the ideal circumstances for conflict (Huggins & Pottierl, 2011). Therefore, understanding the dynamics associated with different types of land rights and tenure is crucial to any agricultural development effort. Lack of assurance of land rights for a long period of time and unequal land distribution hamper agricultural development by limiting land access to many needy Africans, relegating them to the status of land tenants and therefore opening the door to conflict among people.

For sawah technology to succeed and contribute to the realization of Green Revolution in Sub-Saharan Africa (SSA) and particularly Nigeria, it is essential that issues related to the land tenure regime and land rental system are addressed. Land for sawah development must be secured for a long period of time to accommodate the construction of structures such as bunds, canals, and dykes. Improvement of the rice-growing environment through the promotion of lowland sawah technology will be a mirage if land tenure, as it relates to the landlord-tenant relationship, is not addressed. This requires research to examine land rights, the rental system, land conflicts, and conflict-management strategies in Nigeria with a view to improving the use of sawah technology in rice production. This study examined the land rights regime and land rental system as it relates to the development of sawah technology in Nigeria. The specific objectives of the study are to examine: 1) the rental system in sawah production areas in Nigeria; 2) the nature of the land rights regime among landlords and tenants and the land-related constraints faced by tenants farmers; 3) conflict management in the landlord-tenant relationship as it relates to sawah development; and 4) significant differences in farm sizes and he yields of landlord and tenant sawah farmers.

4.2. Land Rights Regime in Nigeria

The land tenure system in Nigeria is based on the Land Use Decree (Act) of 1978, which is used to administer and control land use in the country (Fabiyi, 1984). The Land Use Decree of 1978 reflects the idea that it is in the public interest that the rights of all Nigerians to the land of Nigeria be asserted and preserved by law. The objectives of the decree are to facilitate the rapid economic and social transformation of the country through a rationalization of land use, to enable state governments to bring about proper control and administration of land for the benefit of their people, to remove a main cause of social and economic inequality, and to provide an incentive to development by providing easy access to land for the state and the people. The objectives of the Land Use Decree remain largely unfulfilled several years after its enactment, and titles to land appear to be more insecure now than ever. Indeed, land is less available to the ordinary Nigerian today than it was prior to the Decree, thereby relegating most citizens to an inevitable state of perpetual tenancy.

Land regimes are often categorized as communal, private (individuals), and state (public)(Feder & Feeny, 1991; IFAD, 1995; GTZ, 1998; FAO, 2002).

Communal: A right of commons, according to which each member has a right to independently use the holdings of the community, may exist within a community (Feder & Feeny, 1991). For example, members of a community may have the right to graze cattle on a common pasture. Communal lands also play a significant role in the distribution of land and resources among community members to supplement their daily needs (Harada, 2005).

Private: This form of land regime consists of the assignment of rights to a private party who may be an individual, a married couple, a group of people, or a corporate body such as a commercial entity or non-profit organization. For example, individual families may have exclusive rights to residential parcels, agricultural parcels, and certain trees within a community. Without the consent of those who hold the rights, other members of the community can be excluded from using these resources.

State: Under state property regimes, stewardship of land and natural resources is vested in the state. This means the state owns, manages, and is entitled to income generated from the resource (IFAD, 1995). Property rights are assigned to an authority in the public sector. For example, forestland in some countries may fall under the mandate of the state, whether at a central or decentralized level of government.

Customary land tenure systems in Nigeria are related to family and inheritance systems and are based on the concept of group ownership of absolute rights to land. Each member of the group does not possess land rights on an individual basis; instead, each member possesses these rights jointly with the other members of the community (Fabusoro et al*.,* 2008). Whereas each person has customary rights to land, such rights are usually limited only to the use and transfer through inheritance or renting. Customary land rights establish the basis for access to land resources and the opportunity to use land for productive purposes (Famoriyo, 1980). Famoriyo (1979) noted that three principles have been observed under the customary rules of tenure: 1) each individual member of a landholding family is entitled to a portion of land, enough to feed him or herself and the members of his or her family; 2) no member of the community can dispossess another of his or her stake in family land; and 3) no one can alienate family members' interests in family land without the knowledge and consent of those members. Tenure systems under customary law vary but, in principle, are restricted to usufruct rights. An individual has usufruct rights to the land farmed by his or her lineage or in his or her community area. Individuals can possess land as long as they use it for the benefit of their family or society, can pass the land on to an heir, can pledge its use to satisfy a debt, but cannot sell or mortgage it. The right of disposal belongs only to the community, which, acting through traditional authorities, exercises this right in accordance with customary law. Land rights may be perpetual, for certain limited periods, or solely for the lifetime of the holder (Poguchi, 1962). Although titles to land are generally unrecorded, family and individual rights are usually well known and accepted within the community (Fabiyi & Adegboye, 1977).

Generally, either through communal, state, or private regimes, rights to land differ based on the aforementioned situations. According to Payne (1997) and the FAO (2002), land rights can take the following forms:

Use rights: Rights to use the land for grazing, growing subsistence crops, gathering minor forestry products, and so on. Poor individuals in a community have only use rights.

Access rights: The ease with which communities, households, and individuals acquire land for livelihood-related activities and shelter.

Control rights: The right to make decisions about how the land should be used, including deciding which crops should be planted and how to benefit financially from the sale of crops and so on.

Transfer rights: The right to sell or mortgage the land, to convey the land to others through intra-community reallocations, to transmit the land to heirs through inheritance, and to reallocate use and control rights.

These categories serve as the conceptual framework for land rights used in this study.

4.3. Study Area

This study was conducted in Nigeria, which has a total land area of 923,768 km^2 with varied climate zones. The far south is defined by its tropical rainforest where the annual rainfall is 1,520 to 2,030 mm. Approximately 70% of the population engages in agricultural production at a subsistence level. The study was conducted in Bida (Niger State), Zaria (Kaduna State), Akure (Ondo State), Ilorin (Kwara State), Abuja (the Federal Capital Territory (FCT)), and Abakaliki (Ebonyi State), areas in which sawah rice production technology is being promoted. The specific sites for data collection were Ejeti, Etsusegi, Epagi, Baba, Nasarafu, Shabamaliki, Ajakpe, Sheshibikun, and Etundandan in Bida; Nakala and Millennium Village Pampaida in Zaria; Aule and Ijare in Akure; Ilota, Idofian, Elerinjare, and Ajase-Epo in Ilorin; and Wako in Abuja and Abakaliki.

Bida

Bida is located in Niger State in the central part of Nigeria. Bida is the second largest city in Niger State, with an estimated population of 178,840 (NPC, 2006); it is located on latitude

09° 06 N and longitude 06° 01 E and lies 173.43 m above sea level. Bida is located on dry and arid land. The major ethnic group is the Nupe. It is well known for its traditional crafts, notably brass and copper goblets, other metal products, glass beads and bangles, raffia hats and mats, and locally dyed cotton and silk cloth. Bida is also known for the production of rice cultivated in the floodplains and the inland valley in Niger state; hence the National Cereal Research Institute (NCRI) is located in Bida. Farmers in Bida also produce yams, sorghum, millet, cotton, peanuts (groundnuts), sugarcane, and fruits. The fertility of the soil and availability of water have made Ejeti, Etsusegi, Epagi, Baba, Nasarafu, Shabamaliki, Sheshibikun, and Etundandan more suitable sites for sawah development.

Zaria

Zaria, located in Kaduna State, on latitude 11° 07 N and longitude 7° 43 E is a medium-sized city with an estimated population of 547,000 (NPC, 2006) and a growth rate of 3.5% per annum. The inhabitants of Zaria are primarily members of the Hausa nation. Agriculture is by far the most important activity of the working population. Approximately 40%–75% of Zaria's working population derive their principal means of livelihood from agriculture. Agricultural activity in Zaria can be divided into two types: rain-fed and irrigated farming. Food crops grown include guinea corn, rice, maize and millet, and cash crops include cotton, groundnuts, and tobacco. Zaria, which has a tropical climate with a mean total annual rainfall of approximately 1,100 mm, lies in the natural vegetation zone consisting primarily of woodland known as Northern Guinea Savannah. Soil in Zaria mostly belongs to the class of leached, ferruginous tropical soils, with material that consists of several feet of deposited silt and sand overlying sedimentary decomposed rock. In addition to agriculture, the people of Zaria are also employed by the textile industry.

Akure

Akure, the capital city of Ondo State, is located on latitude 7° 25 N and longitude 5° 20 E. The people of Akure belong to Nigeria's Yoruba ethnic group. It has a population of about 500,000 and is characterized by a warm humid tropical climate, with an average rainfall of about 1,500 mm per annum. Annual average temperatures range between 21.4°C and 31.1°C, and its mean annual relative humidity is about 77.1%. The vegetation in this area is of the tropical rainforest type. Akure lies on a relatively flat plain within the Western Nigerian plain and is about 250 m above sea level. Akure has a relatively dry season from November to March and a rainy season from April to October. Although cocoa is by far the most important local commercial crop, cotton, teak, and palm produce are also cultivated for export. Arable crops grown include yams, cassava, maize, bananas, rice, okra, and pumpkins.

Ilorin

Ilorin, the capital city of Kwara State, is located between latitudes 8° 24 N and 8° 36 N and longitudes 4° 10 E and 4° 36 E and occupies an area of about 100 km^2. It is dominated by the Yoruba people from southwestern Nigeria and is situated at a strategic point between the densely populated southwestern and the sparsely populated middle belt of Nigeria. Ilorin is located in a traditional zone between the deciduous woodland of the south and the dry savannah of the north of Nigeria. The climate of Ilorin is characterized by both wet and dry seasons. The temperature of Ilorin ranges from 33°C to 34°C from November to January and from 34°C to 53°C from February to April. The total annual rainfall in the area is about 1,200 mm. The soil is loamy and supports the growth of cereal crops. Agricultural crops grown include groundnuts, yams, cassava, guinea-corn, rice, maize, beans, and vegetables. The availability of lowland with fertile soil made Ilota, Idofian, and Ajase-Epo suitable for the adoption of sawah technology.

Abuja

Abuja, the Federal Capital Territory (FCT), is located between latitudes 8^o 25 N and 9^o 25 N of the equator and longitudes 6^o 45 E and 7^o 45 E. The territory covers an area of 8,000 km^2 and is bordered by four states: Niger to the West, Nassarawa to the East, Kogi to the South, and Kaduna to the North. Abuja has a population of 1,405,201 (NPC, 2006). The inhabitants are traditionally members of the Gwari ethnic nationality, but people from all over Nigeria now reside in this territory. Migrant farmers from Benue and Kogi are also found in the territory. Abuja falls within the Guinean forest-savanna zone of the West African sub-region and features a tropical wet and dry climate. A number of local soils have been identified within Abuja, and these include alluvial soils, luvisols, and entisols. The rainy season begins in April and ends in October, with a rainfall of about 1,500 mm during the rainy season. The sawah site in Abuja is located in Wako, a village in Abuja. Wako village is a host community for both the indigenous Gwari and the migrant farmers from neighboring Benue and Kogi states. The accessibility to the Nigerian seat of power in Abuja, labor from both native and migrant farmers, and the perennial water source in Wako made it suitable for sawah development.

Abakaliki

Abakaliki is the capital city of Ebonyi State in southeastern Nigeria located on latitude 6° 20 N, and longitude 8° 6 E. The inhabitants are primarily members of the Igbo nation. Abakaliki is made up of three clans: the Ezza Ezekuna, Izzi, and Ikwo and has an estimated population of 141,438. Abakaliki, which lies at the intersection of Enugu, Afikpo, and Ogoja Roads, is commonly referred to as the food basket of southern Nigeria. The city has been a leading producer of rice, yams, and cassava for decades. The soil is texturally clay loam with gravelly sub-soil in some locations, especially the upland areas adjacent to the lowland areas. Abakaliki soil is believed to be among the best for rice production in Nigeria, especially for the popular "Abakaliki Rice." This has attracted partnerships among the Abakaliki Rice

Farmers Association, the Abakaliki Rice Mill Owners Association, the Ebonyi state government, and some international agencies like USAID and UNIDO to improve rice production in the state. The rainfall pattern is bimodal, with peaks in the months of July and September. Annual rainfall stabilizes around May and stops around October, leaving a dry period between November and April.

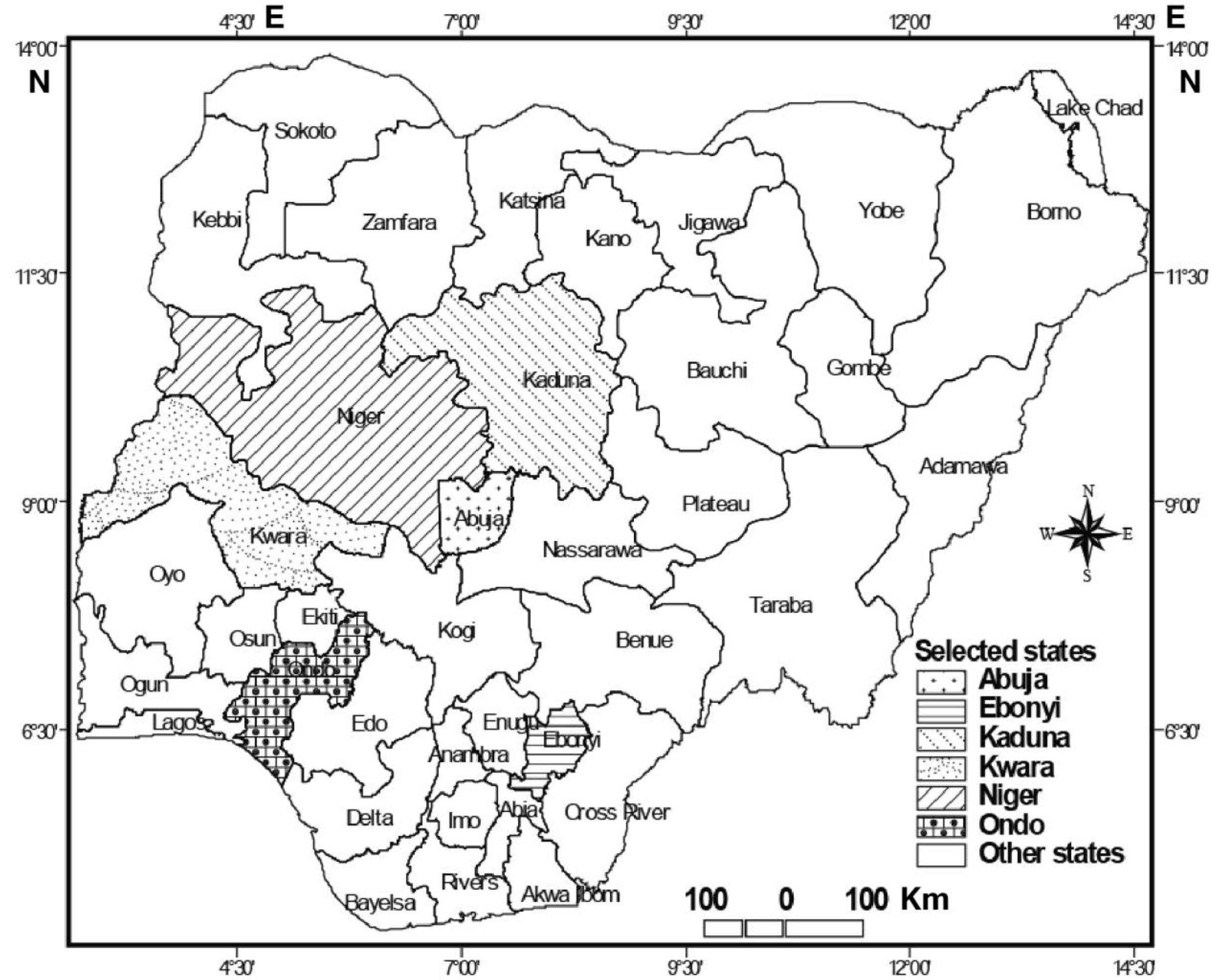


Fig. 1. Map of Nigeria showing the study area.

4.4. Methodology

Sampling and Data Analysis

A sample of 124 sawah rice farmers was selected randomly from a list of rice farmers farming at the sites. Data used in this study were collected from October 2009 to January 2011 in all the sawah sites in Nigeria. The availability of inland valleys is a prerequisite for the adoption of sawah rice production technology. Farmers were selected based on their participation in sawah rice production. Data used in this study were collected in all the sites using interview guide. In addition to the interview guide, discussions were held with randomly selected farmers and key informants, including community leaders. These discussions helped to provide detailed information, especially about conflicts and conflict management, topics perceived as "delicate" by farmers. The nature of the land rental was determined by whether the tenant farmer was paying money (cash) for the use of the land or giving the landlord part of his/her farming proceeds (paddy) in kind or both. The amount paid for rent and the quantity of the paddy given to the landlord were also recorded. Rights to the land were categorized as the right to use, right to control, and right to transfer land. The yield was determined by measuring the produce harvested from the cultivated sawah area in kilograms. Farm size was measured in hectares using a Geographic Positioning System instrument (GPS). Descriptive statistics were used to analyze the socioeconomic and farming characteristics of farmers. *T*-tests were used to determine significant differences in the yields and farm sizes of landlords and tenant farmers. As shown in Table 1, sawah rice farmers are predominantly male with average age of 42.3years; few elderly farmers are involved in sawah farming. The majority have Quranic education, and are Nupe, a tribal people from north-central Nigeria. The household size of farmers ranged between one and 40, with a mean of 14. These members of the household may serve as source of labor that can be used on the farm. The mean size of farms using the sawah system is 0.53 ha; however, the majority of farmers have farms consisting of less than 0.5 ha and have a mean income of ₦151,110 (US$1,041 with an exchange rate of ₦145 to US$1 at the time of data collection in 2009). The mean number of years of experience with rice production and the mean number of years of experience with rice sawah production (adoption of sawah system of rice production) were 32 and 6, respectively. Thus, the respondents have accumulated enough experience with rice production to be capable of using sawah technology. Additionally, their experience with rice production is of great importance when developing the skills required for sawah rice production. The mean yield of rice from the sawah fields is 2.5 tonnes, with a majority of farmers having a yield of less than 2 tonnes. The yield corresponds with the size of the field. The yield of sawah fields among the sawah farmers is 4.65 tonnes per hectare.

Table 1. Socioeconomic characteristics of respondents

Attribute	Definition	Distribution
Sex	Sex of the respondents as male or female	Male (98.9%); Female (1.1%)
Age	Actual age of respondents	Average age = 42.3
Educational level	Highest educational attainment	Quranic (62.7%); No formal Education (3.6%); Primary (12.0%); Secondary (18.10%); Tertiary (3.6%)
Ethnicity	Ethnic affiliation	Nupe (73.4%); Lada (9.7%); Hausa (8.1%); Igbo (7.3%); Yoruba (1.6%)
Household size	Number of persons in the household	Average = 14 persons
Yield	Yield from the sawah farm	Average = 2.5 tonnes
Farm size	Area of land used for sawah	Average = 0.53 ha
Income	Income generated from sawah production	Average = ₦151,110 (US$1,041)
Years of experience in rice production	Number of years spent in rice farming	Average = 32 years
Years of experience in sawah rice production	Number of years spent in Sawah rice farming	Average = 6 years

4.5. Results and Discussion

Land Rental in Sawah-based Rice Production

Two main rental arrangements were identified in the study area: (a) land-for-paddy, and (b) land-for-cash. In the case of land-for-paddy, both landlord and tenant agree that the tenant will give some of his yield to the landlord after the harvest as rent. In the case of land-for-cash, the tenant pays an agreed amount of money to the landlord on an annual basis before using the land. The most common arrangement in the study site was land-for-paddy. As shown in Table 2, 76.1% of rental agreements were under the land-for-paddy system. According to this arrangement, the tenant farmer gives 5% of the total rice yield to the landlord. As reported by Robertson (1987), high risk, price fluctuations, and the subsistence character of non-capitalized agricultural production in Africa are significant and important reasons for entering into this type of arrangement. The landlord and tenant share both the benefits and risks involved in the use of the land.

With respect to the land-for-cash system, the average annual rent at the study sites was ₦12,000 $ha/^{1}year^{-1}$ (US$82 $ha/^{1}year^{-1}$). Rent is based on local knowledge of land supply/demand interactions over time and experiences with the production cost/return structure among the people. The rent is fixed in advance in the form of a verbal agreement between landlord and tenant. This arrangement is considered to be mutually beneficial for both landlord and tenant, and the agreement is believed to be fair to both parties. The duration of the agreement ranges from 2 to 15 years, and payment is made on an annual basis. As part of the agreement, landlords reserve the right to take over the land from the tenants in situations of refusal to pay rent, subletting land to other tenants, failure to renew the agreement on expiration, non-observance of local customs, and social abuse in the community. Special cases occur in which tenants pay the rent in cash before using the land and also give part of their yield to the landlords after the harvest. However, this arrangement is based on mutual agreement between landlord and tenant.

The release of land in the study locations to tenants by landlords is based predominantly on ethnicity, social status, and relationships. Landlords prefer to give land to farmers from the same ethnic group but sometimes will rent to farmers from another ethnic group based on their social relationships and social status. According to the respondents, this practice is intended to minimize the occurrence of conflicts resulting from rental arrangements. Other factors that contributed to the decision between landlord and tenant to enter into tenancy agreements include labor supply opportunities, access to resources and inputs, and risk (Lastarria-Cornhiel & Melmed-Sanjak, 1999).

Table 2. Land rental in sawah-based rice production

Type of rent	Frequency (%)	Payment/cost	Nature of agreement	Security of tenancy
Land-for-cash	2 (4.4)	₦12,000 ha^{-1}year^{-1}	Verbal	Not secured
Land-for-paddy	35(76.1)	5% of total yield	Verbal	Not secured
Both (Land-for-cash and land-for-paddy)	9 (19.6)	₦12,000 ha^{-}1 year-1 at the beginning of year and 5% of total yield on harvest	Verbal	Not secured

Land Rights for Landlords and Tenants Involved in Sawah-based Rice Production

The land rights system examined in this study does not provide free access to the land in the study locations. All lands are designated based on the communal system (Table 3) and are allocated to individual owners, who then have use of, control over, and transfer rights related to the land (Table 4). Thus, control over the land rests solely with the landlords. They decide the size of the land to be cultivated by tenants and may prevent tenants from expanding the size of their sawah farms. Transfer rights related to the land (from one person or generation to another) also rest solely with the landlords, allowing them to rent it out, share its usage, leave it fallow, bequeath it, or sell it. However, these land-use decisions require consultation with family members who may share inherited ownership of the land. This consultation is necessary to avoid conflicts over land use and maintain appropriate communal land designations and rights. Table 4 presents a summary of situations pertaining to land rights at the study sites. Landlords can give parcels of his/her land to a tenant only after due consultation with family heads and other family members.

This study identified four categories of tenants: (a) farmers with migrant lineage who, irrespective of length of stay in the location, do not have inheritance rights to community land; (b) farmers whose land was fallow during the cropping season; (c) farmers who have lost their land to land degradation (mainly erosion); and (d) farmers without access to lowland suitable for sawah production (in this case for rice production). These groups of farmers have similar rights to land according to the communal regime. Land tenants have only the right to use the land, and restrictions are imposed by landlords, local customs, the customary tenure regime, and other social factors. These restrictions have become the norms governing land rental at most sites and therefore guide agreements between landlords and land tenants.

In most cases, tenants are restricted to growing rice and several arable crops on sawah land, whereas the landlord is free to cultivate any crop. The tenant is not allowed to transfer land to another tenant and is also prevented from erecting certain structures, such as farmhouses and storehouses for harvested grains, on the land. Tenants are restricted from leaving the land fallow and are not allowed to grow permanent crops on the land. A limit is also imposed on how the tenant can use the land for the grazing of their small ruminants after harvesting their rice. The short period of tenancy sometimes prevents tenants from constructing structures that are needed to create the sawah plot. Based on observations made at the study sites, land use among tenants is not secure, and the landlord may decide to take over land at anytime so desired.

Since the introduction of the sawah method of rice production and the drastic increase in the yield of farmers, the process by which land is accessed for this purpose has become more competitive among farmers. Landlords now rent larger sawah farming plots in upland than lowland areas. The control exerted by many landlords can be a source of conflict and, in many cases, is a source of insecurity for tenants. It also limits the participation of landless people in sawah rice production.

Table 3. Sources of land in the study area

Variable	Measurement/definition	Percentage
Land Tenure	Private	0
	Customary	100
	State	0
*Sources of Land	**Own	12.1
	Rent	37.1
	Inherit	71.8
	Gift	2.1
	Sharecrop	1.6
Factors influencing land acquisition	Ethnicity	82.4
	Social relationship	63.9
	Social status	15.1
	Financial factors	0.8

*Multiple responses provided; ** Land tenure: Some farmers said that they did not inherit the land they are using and also do not rent the land. However, they proved that they had been using the land for so many years that it cannot be taken from them. Because it was not possible to determine the sources of their land, the authors decided to classify their land as owned to distinguish them from those who inherited their land.

Table 4. Land rights of landlords and tenants

Rights	Landlords	Tenant farmers
Right to use: • Right to use the land for grazing • Right to use the land for growing subsistence crops • Right to use the land for gathering minor forestry products • Right to choose type of farming • Right to leave the land fallow	No limitations	Limited to sawah rice production
Right to control • Right to make decisions about how the land should be used	No limitations	No right to control land use. Land can be used only for sawah production
Right to transfer • Right to convey the land to others through intra-community reallocations • Right to give out one's land • Right to hire out one's land and to re-allocate use and control rights • Right to sell or mortgage the land	Consultation with family members	No right to transfer
Security of land	Secured	Not secured
Who makes land-use decisions?	Self, in consultation with family members	Landlord

Accessing lowland and upland areas: Do the methods for accessing the lowlands for rice production differ from those for accessing the uplands?	Both uplands and lowlands are accessed by inheritance	Both are accessed by rental but the lowlands now attracts more attention and competition than does the uplands

Land-related Constraints Faced by Tenant Farmers

As shown in Table 5, the major problems faced by tenant farmers in accessing land for sawah production are distance to farms, land availability, short duration of tenancy periods, acquisition of land, and interference from other landlord farmers. Farmers travel as far as 15 km from their houses in search of suitable sites for sawah development due to the nature of land ownership in the study area. For this reason Oladele & Wakatsuki (2010) suggested that constraints related to wasted time and traveling long distances to rice fields be addressed to make more time available for farm work. Most roads leading to farmers' fields are in a deplorable condition, which renders the transport of inputs and yields in and out of farms difficult. The period of tenancy and interference from landlords sometimes create problems for tenant farmers who rent land.

Due to the increase in yields from sawah rice fields compared with those following traditional methods, from 1.5 tonnes per hectare (WARDA, 1999) to 4.65 tonnes per hectare based on the results of this study, most landlords have resorted to either increasing the rent on their land, which has had a considerable effect on tenants, or refusing to renew the tenancy (Oladele & Wakatsuki, 2010). The difficulties faced by farmers related to acquiring land for sawah have become associated with the use of sawah technology. Additionally, farmers have cited ineffective governmental policies on land as a constraint. The 1978 Land Use Decree in Nigeria, instead of solving farmers' problems, has compounded the stress they experience as they try to secure land for agriculture. Indeed, today less land is available to the ordinary Nigerian than it was during the period prior to the Decree, thus rendering most citizens to a state of perpetual tenancy (Olayiwola & Adeleye, 2006).

Table 5. Land-related constraints and severity of constraints

Constraints	*Very severe (%)	Severe (%)	Somewhat severe (%)
Accessibility problems due to long walking distance	31.9	20.2	47.9
Scarcity of sawah plots	21.0	20.2	58.8
Disputes and conflicts	0.0	0.0	100.0
Tenancy payments	0.0	0.0	100.0
Duration of tenancy	0.0	6.7	93.3
Interference from landlords	8.4	0.0	91.6
Ineffective government policies	0.0	0.8	99.2

*Likert Scale: Very severe = 3; Severe = 2; Somewhat severe = 1. The Likert scale is a scale used for the assessment of the severity of the constraints.

Conflict Management in Landlord–Tenant Relationships in the Context of Sawah Development

A qualitative survey of conflict-management approaches was conducted at the sawah sites. Case studies of the nature of conflicts, causes of conflicts, and conflict-resolution methods adopted are discussed in this section with the aim of studying the present to prepare for the future of sawah development in Nigeria.

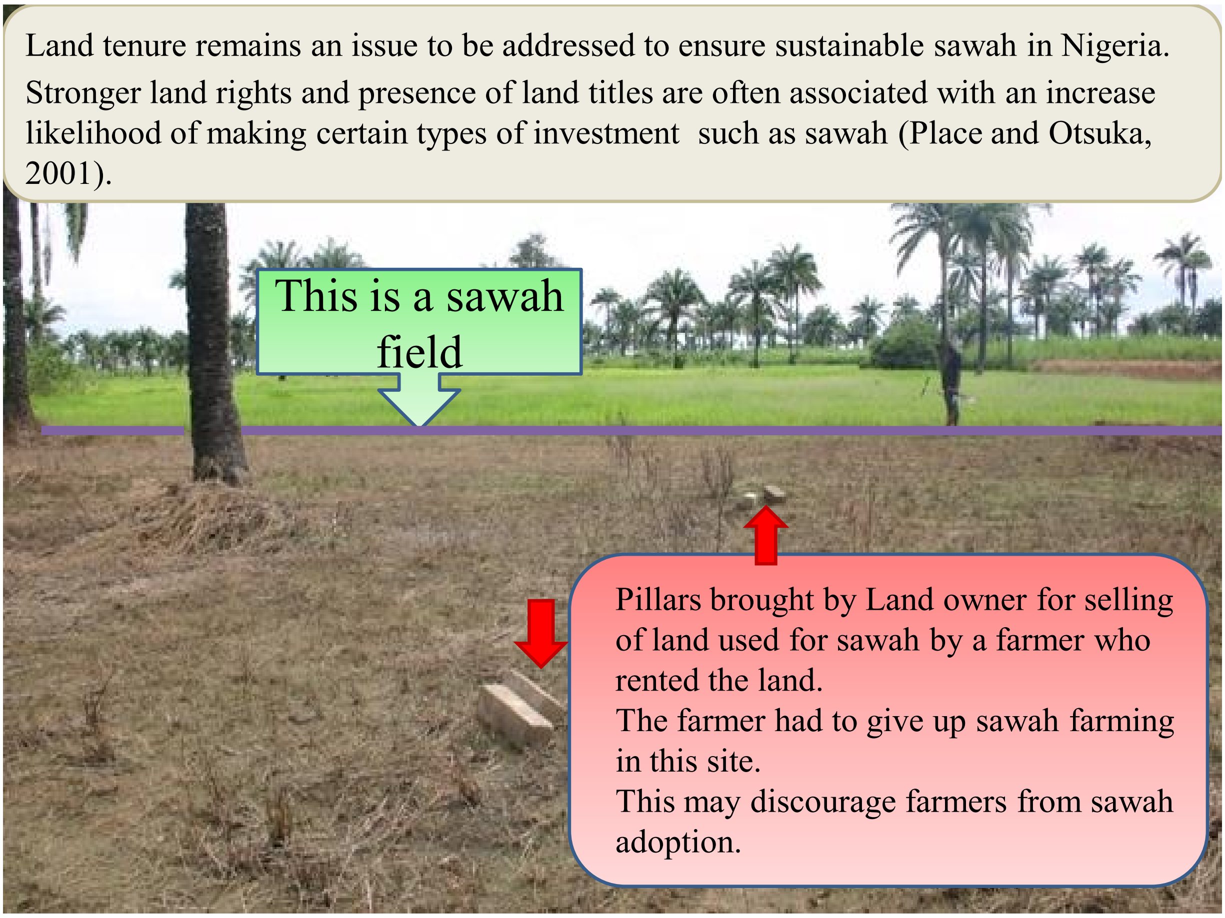
As shown in Table 6, land conflicts were recorded in the Ilorin, Bida, and Abuja sawah sites. The conflicts involved inter-communal (involving villages) and landlord-tenant disputes over the land used for sawah rice production. Conflicts among the parties involved were caused by the lack of proper demarcation between communities (villages) and landlords' attempts to enforce their land rights on their tenants. In Kwara State, two villages, A and E, [(1)] share a common boundary with a large expanse of lowland. A parcel of land given to a tenant by a landlord in village A for sawah cultivation in the 2008 cropping season led to an inter-communal conflict. Villages A and E both claimed ownership of the land. As this persisted, the tenant farmer was not allowed to farm the land. Efforts to settle the matter proved unsuccessful. Hence, the land was left uncultivated for two seasons, 2008 and 2009, after the initial investment by the farmer in bund construction, canal construction, and farm layout. A similar inter-communal type of conflict occurred between villages M and J in Bida, Niger State, where native farmers from the villages claimed ownership and control over a parcel of land suitable for sawah rice production. The competing claims of land ownership led to a conflict between the two neighboring villages. Due to this conflict, no farmer was allowed to use the land. In village B of the Federal Capital Territory in Abuja, the land conflict involved the landlord and tenant. The conflict erupted when the landlord farmer decided to take over the land because the tenant obtained a higher yield from the sawah plot. Because the period of tenancy had not expired, the refusal of the tenant to vacate the land led to conflict between the two parties.

Attempts to resolve these conflicts by communities have involved dialogue, litigation, and mediation through a third party. Mediation is a voluntary, negotiation-based process in which the parties involved in a current or potential dispute meet with the assistance of a neutral and impartial mediator for collaborative problem solving and consensus building with the goal of achieving a mutually acceptable resolution (Andrew, 2003). As a result of dialogue, the conflict at villages A and E was resolved with the intervention of the Ilorin sawah management team, who operated with the assistance of the village extension agents and the traditional rulers of the villages. Participation of the involved parties in the two villages was sought, and the conflict was resolved amicably. Both communities agreed that the farmer should be allowed to use the land for sawah rice cultivation. It must be noted, however, that the land ownership had not yet been determined at the time of data collection. In the case of village B, the intervention of traditional leaders assisted in resolving the conflict. After the intervention, the landlord farmer willingly released the land to the tenant. In the case of villages M and J in Bida, the parties employed police litigation and the conflict had yet been resolved at the time of data collection. Ownership of the land will be determined by the law court.

Based on our observations, it appears that the dispute settlements imposed on parties or negotiated within the shadow of the law can elongate the conflict period and may not eliminate the real sources of the dispute. This process of conflict resolution may actually disrupt relationships rather than solve problems. Disputes are resolved only when the parties themselves reach what they consider to be an acceptable resolution and the settlement of issues is based on a consensus among all parties. Conflicts over land may contribute to decreased agricultural production and land insecurity. Deininger & Castagnini (2006) have shown that the outputs of plots affected by conflicts are clearly lower than are those of plots not affected by conflicts. Land conflicts are the most evident social manifestations of land insecurity (Idowu, 2006), and land insecurity is a major contributing factor to extreme poverty and social instability, including conflicts and civil unrest, rural migration, land abandonment, and poor economic growth (FAO, 2002). The estimated magnitude of productivity losses due to land conflict, between 5% and 11%, is very large, albeit consistent with descriptive evidence that points to a number of ways in which land conflicts lead to highly disruptive economic consequences (Deininger & Castagnini, 2006).

Table 6. Land-related conflict management at the research sites

Location	Occurrence of conflict	Form of conflict	Causes of conflict	Management and resolution
Akure	No	None	None	None
Ilorin	Yes	Inter-communal	Land demarcation	Dialogue
Bida	Yes	Inter-communal	Land demarcation	Litigation
Zaria	No	None	None	None
Abakaliki	No	None	None	None
Abuja	Yes	Landlord–Tenant	Right enforcement and tenancy dispute	Third-party intervention



Land Tenure is a problem facing Sawah Development in Nigeria

Significant Differences in the Yields and Farm Sizes of Landlord and Tenant Farmers

We found a significant difference (t = 3.424) in the farm sizes of landlords and tenants (Table 7 and Fig. 2), implying that land rights determine the farm size at sawah sites in this country. This result further implies that the access of tenants to land is not equal to that of landlords. The kind of rights and tenure possessed by an individual determines control over land, including the amount of the land that can be used for agricultural production. This, in turn, can produce disparities in agricultural income. Jayne et al. (2003) found serious disparities in income and land allocation in five countries in Africa. Their research found that 25% of rural agricultural households in Ethiopia, Rwanda, Kenya, Mozambique, and Zambia were virtually landless, having access to 0.1 ha per capita or less in each country. This situation could also affect the adoption of sawah technology in Nigeria.

Additional results show significant differences (t = 3.167) in the yields of landlords and tenants. Although the implications of this were not subjected to further econometric tests, the preliminary interpretation is that landlords have a significant influence that grants them access to certain important information that can be useful in improving production practices. The opportunity to control land also places landowners at an advantage in terms of receiving regular advice from agricultural extension officers. Land can be used as social capital and can constitute an economic advantage in agricultural production. The security of tenure can also provide sufficient insurance against farm-related risks, which, in turn, are related to increased investment in farms over the medium- and long-terms. Sawah development involves the construction of structures such as bunds, canals, and dykes, which require land with secure tenure (either permanent or for a reasonable number of years) for the farmers to break even on the investment.

Hayes et al. (1997) reported that within the customary tenure system, more individualized rights are associated with a higher propensity to make investments; this, in turn, had a positive effect on yield. Lack of security with regard to land as a result of renting hinders tenants from investing in such structures and leads to reductions in the yields from sawah farms. The lack of secure ownership rights to land reduces farmers' incentives to invest in yield-increasing inputs and to put land to its most productive use (Johnson, 1972; Besley, 1995; Hayes et al., 1997; Feder et al*.,* 1988; Roth & Dwight, 1998). A study conducted in Thailand also showed that secured lands are characterized by higher investment demand and input intensity and, as a result, yield was higher on secured lands than on lands without titles (Feder et al., 1988). Place and Hazell (1993) reported that parcels of secured land have received more drainage or liming improvements than those with no secured rights; they noted that these improvements increase farm output**.** In Niger, Gavian & Fafchamps (1996) reported that tenure insecurity stimulates farmers to divert the scarce manure resources used for improving farm yields from less secure or borrowed land to more secure or owned land whenever they can. A study of the effects of land tenure on the production behavior of farmers in rural China conducted by Li et al. (1998) showed that the right to use land for long (or indefinite) periods of time encourages the use of land-saving investments such as organic manure, but that the use of short-term inputs was not affected by such rights.

Table 7. Difference in the yields and farm sizes of landlord and tenant farmers

Variables	Landlord farmers ($N = 89$)	Tenant farmers ($N = 46$)	*t*-value
Farm size (ha)*	41.50	15.84	3.424
Yield (kg)**	216,680	69,560	3.167

*: significant at $P < 0.05$, **: significant at $P < 0.01$

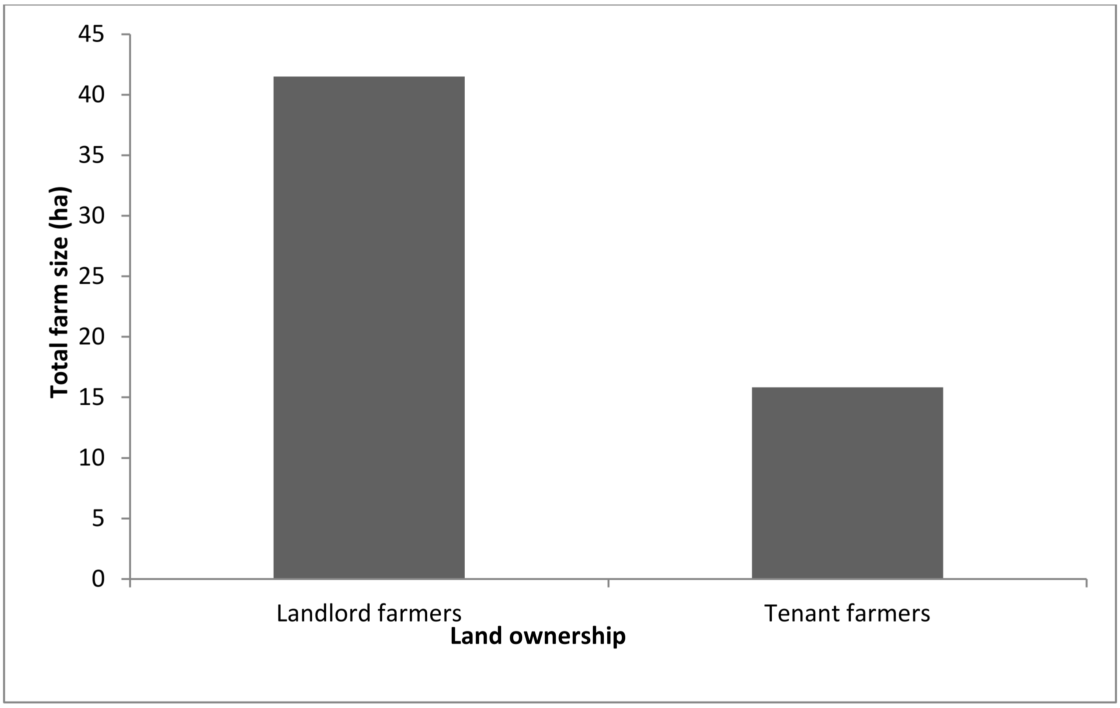


Fig 2. Size of farms at sawah sites.

4.6. Conclusions and Recommendations

The land rights of landlord and tenant farmers in sawah sites in Nigeria are characterized by disparities between the two parties. The rights and control over land by tenants are limited and constrain attempts to improve production and invest in farms. Access to and control over land also places landowners at an advantage in the adoption of any technology. As sawah technology promises higher yields for rice farmers in Nigeria, it also requires substantial investment in the construction of canals, bunds, and dykes, which only the landlords have the right to do. This calls for an institutional approach to ensuring more secure rights and longer tenancies on land for tenants, which would allow for growth and investment in the land. Access to land for tenants will enhance their participation in sawah and increase their chances of increasing their income and emerging from poverty. Investment in more durable inputs such as power tillers, dykes, and irrigation canals will decrease if land is not secured.

Therefore, tenants and landless people need more secure access to land to provide them with opportunities to manage their sawah plots so that they will have higher yields. Farmers whose land security is not guaranteed would be more inclined towards short-term investments in land, and the sustainability of sawah would not be expected to be their priority. More social capital is also needed because the land rights and the rental system at the study sites are entrenched in the communal tenure arrangement. Expanding the sphere of social capital between the landless and the landowners could ensure productive negotiations and create effective communication. This will also help to reduce conflict.

Notes

(1) A, E, M, J, and B are not the real names; given the sensitive nature of land conflicts and the possibility that further research will be conducted in these villages, the authors decided to use letters in place of names.

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CHAPTER 5

Constraints to Sawah Rice Production System in Nigeria

6.1.Introduction

In order to increase food production and alleviate the widespread poverty in Sub-Sahara Africa (SSA), given the limited possibility for expansion of cultivable area and increase in population, there is need for a Green Revolution (GR) (Diao et al. 2008; Otsuka and Kijima 2010). GR enhances crop yield per unit of land by using high-yielding varieties, irrigation and agrochemicals such as fertilizers, pesticides and herbicides. The speed and scale with which it solved the food problem was remarkable and unprecedented, and it contributed to a substantial reduction in poverty and the launching of broader economic growth in many Asian countries. Improved cereal varieties, fertilizers, irrigation, and modern pest control methods lay at the heart of the GR (Otsuka and Kijima 2010).

Wakatsuki (2008) noted that to realize green revolution in Sub-Saharan Africa, it is essential to improve rice-growing environment by promoting lowland sawah system. This is because the sawah system utilizes the inland valleys which are reported to be high in fertility and through appropriate water management, fertility can be sustained and enhanced for rice production (Wakatsuki and Buri 2008). Among all the wetland environments, inland valley is regarded as having the highest potential for agriculture intensification and rice production. Based on the inventory data of inland valleys in West Africa, inland valley area in Nigeria for small scale irrigated sawah is between 6 to 7 million ha, which is about 7% of total land area, 10-12% of Guinea Savannah Zone and 63-74% of the Humid Forest Zone of the country (Fu et al. 2009). Sawah is a levelled rice field surrounded by banks with inlet and outlet for irrigation and drainage. The basic elements of sawah system include improved irrigated rice basins, seedbed preparation, transplanting and spacing of seedlings, fertilizer application and most importantly, appropriate water management. Fashola et al. (2006) also reported that the sawah system offers the best option for overcoming the constraints of rice production in Nigeria, namely poor soil fertility, poor water management and poor varieties.

Sawah rice production system was introduced to the inland valley of Nigeria because it can overcome soil fertility problems through enhancing the geological fertilization process, conserving water resources, and the high performance multi-functionality of the sawah type wetlands (Oladele and Wakatsuki 2008). Sawah-based rice production took off through the establishment of a demonstration farm (1.5 ha) at Ejeti village in Bida, Niger State in 2001 (Oladele and Wakatsuki 2008). The goal of sawah rice production is development of sustainable production systems of the whole watershed, which allows intensification and diversification of the lowland production system. Studies have highlighted the potentials of sawah technology for achieving relatively high yields while effectively protecting the soil (Fashola et al. 2006; Oladele and Wakatsuki 2008). The mass adoption and sustained use of sawah technology are also important due to the resulting environmental benefits.

According to Guerin and Guerin (1994) there are several constraints to the adoption of technologies and innovations by farmers. These included the extent to which the farmer finds the new technology to be complex and difficult to comprehend; how readily observable the outcomes of an adoption are; its financial cost; the farmer's beliefs and opinions towards the technology; the farmer's level of motivation; the farmer's perception of the relevance of the new technology; and the farmer's attitudes towards risk and change. Lack of fertilizer, infestation by weeds, insect pests and diseases were the major constraints that negatively and significantly influenced the decision to adopt improved rice varieties in Nigeria (Awotide et al. 2010). Okpukpara (2010) reported that credit and availability of modern input in the rural areas appear to be the major constraining factor in adoption of modern technologies in Nigeria.

Guerin (2002) highlighted three major categories of constraints that affect an innovation. The first category relates to users and includes factors such as personality, goal and objectives of using the technology, educational level, and degree of motivation. The second emphasises the characteristics of the innovation itself and issues associated with the developers of the innovation. The third area deals with the role of extension agents and the transfer process. Lack of financial capital has been cited by farmers as a major reason for not adopting beneficial technologies (Agricultural Technology Adoption Initiative (ATAI) 2011). In many developing countries, and particularly in rural areas, access to financial services including credit and formal saving mechanisms is limited (ATAI 2011). Even where financial services are available, they are often highly disadvantageous to smallholder farmers. For example, within a single market, interest rates often vary according to the characteristics of the borrower and the activity being financed (Esenwa 2011).

However, none of these studies has identified the constraints faced by farmers in adoption and use of sawah technology in Nigeria. Identifying the constraint faced in the use of sawah technology will assist in the expansion of its adoption across Nigeria. Therefore, this study identified the problems faced by farmers in the use of sawah system. Specifically, the present study identified the constraints (which included land acquisition and tenure, economic, market, information and communication) and farmers' attitudes to sawah practice in Nigeria. The study further examined the inter-relationships between the constraints identified.

6.2.FACTORS AFFECTING ADOPTION OF AGRICULTURAL TECHNOLOGY

Past studies have identified barriers to agricultural technology adoption. Among the barriers identified by Food and Agriculture Organization of the United Nations (FAO 2001) are large investment costs, the perceived risk of a technology, long gestation periods for the benefits of the technology to materialize, access to information and extension services, land tenure and culture and recent history. The socio-economic status such as family income, parental educational level, parental occupation and social status all affect adoption (Demarest et al. 1993). In Kenya, for instance, some of the socio-economic factors reported as constraints to technology adoption include high initial investment cost, negative image and limited private sector involvement.

Bangura (1983) argued that the best predictor of adoption was the farmers' individual goals. If there are differences in the goals of technology and the farmers' goal, achieving success by the farmers in the use of innovation will only be a mirage. The farmer's socio-economic status can also pose a threat to his/her farming activities. The characteristics of an innovation can also create a problem to the farmers. Innovations that are simple and relatively easy to understand are more likely to be adopted by the farmers than those that are complex. Bangura (1983) reported that farmers prefer to adopt innovations that satisfied their security needs, are less complex, required less time to use, and are less labour-demanding. Such innovations are easily communicated in a short time to intending users/farmers.

Kumar and Popat (2010) reported that farmers' characteristics such as knowledge, market orientation and innovativeness influenced the adoption gap significantly. A lack of knowledge about an innovation can limit its adoption. Attitude, knowledge, skill and the personality of scientists and extension agents can also constrain the use of an innovation.

Scientists have often been criticised for lacking the skills necessary for implementing their innovations. In addition, farmer's knowledge of innovation is an important factor in the adoption process. Lack of technical know-how on the use of technology by farmers can be a serious constraint to the adoption and the success of that innovation. Sawah as a package of innovation has some component elements, and mastery of its components will determine its successful adoption. Sawah components include bunds construction, puddling, flooding and flood control, levelling and smoothening, dyke construction, canal construction, seed selection, transplanting, fertilizer application, use of sand bags, water management, weed management, diseases and pest management, and nursery preparation.

The results of some research are easily observed, and are therefore easier to communicate. Innovations with a high degree of observability are more likely to be adopted. It is recognised that some innovations do not lend themselves readily to communication and this is one of the most common constraint in innovation adoption process. However, the impact of communication in human development is enormous and must be taken into cognisance in the field of agriculture where the systems that form the entity are stratified into a highly educated technology generation system (researchers), a relatively well educated technology dissemination system (extensionists) and a mass of technology utilization system (farmers) who have little or no formal education (Adeniji 1997). The identification and use of appropriate communication channels is important. For example, it is unlikely that the use of mass media in extension can replace personal contact between extension agents and target groups or individual farmers. If an innovation is complex and its cost and expected returns are difficult to identify, and the adoption challenges the farmer's belief, then communication from researcher to extension agent and ultimately to the farmer must be extremely clear hence the adoption faces a great problem. There is a need for continual access to information and in this regard extension agents have an important role to play as knowledge navigators.

The use of improved technologies remains a major strategy for increasing agricultural productivity and promotes food and livelihood security. Innovations may include scientific and technical knowledge, ideas, services, systems, inventions, and products. The adoption of the improved technologies requires particular biophysical conditions such as slope, soil texture which are in general well described in common manuals and relatively easy to verify (Drechsel et al. 2010). A complex situation arises from the social, cultural and economic perspectives. It is believed that the biophysical requirements are less limiting for technology dissemination than socio-economic factors. Drechsel et al. (2010) noted that the adoption of any technology is a function of the characteristics of the technology proposed, farmers' perception of its advantages and need, as well as availability and distribution of production factors. Other factors that affect the adoption of any technology are farmers' attitude towards experiments and risk, institutional support/knowledge sharing and the policy environment surrounding the technology.

6.3.Methodology

Descriptive statistics were used to analyze the socio-economic and farming characteristics of the farmers. Correlation analysis was used to determine the inter-correlation between the constraints and other study variables. Regression analysis was used to determine the relationships between the yield and constraints as predictor variables as shown in the equation below:

$$Y = a + \beta X_1 + \beta X_2 + \beta X_3 + \beta X_4 + \beta X_5 + \beta X_6 + \beta X_7 + \beta X_8$$

Where

Y = Yield

X_1 = Land acquisition and tenure

X_2 = Production and on-farm constraint

X_3 = Economic market constraints

X_4 = Input availability related constraints

X_5 = Information and training constraints

X_6 = Technological and scientific constraints

X_7 = Attitude and perception constraints

X_8 = Total constraints

6.4.Results and Discussion

Constraints to Sawah Technology: The constraints to sawah development in Nigeria are presented in Table 1. The most severe constraints related to land acquisition and tenure were poor fertility of the soil (76.10%), poor road network from their farms to city centre (87.50%), and topography of the farm that results in high cost of levelling of sawah basins (84.10%). Infrastructure such as roads and irrigation plays a key role in facilitating technology adoption. Improved transportation is also associated with diffusion of technology, better use of inputs and better prices for farmers. (ATAI 2011). However, accessibility, availability, conflict and land fragmentation also affect the sawah development. Land tenure security determines whether people will invest in and adopt sawah technology and can therefore be regarded as an important ingredient in adoption of sawah technology. Sawah development needs a secured land on which structures such as bund, canals and dykes should be constructed if not permanently but for a reasonable number of years. According to FAO (2001) land tenure and barriers related to land availability are major constraints to agricultural intensification. Production and on-farm constraints severely affecting sawah development were water management (86.10%) and flood (48.90%). Other on-farm constraints are drought, weeds, pest and diseases. Wakatsuki (2008) reported that an improvement of the natural resource management technology, especially through the improvement of water control in rainfed lowland plays a major role in increasing rice production among farmers.

The major economic constraints faced by sawah farmers are lack of viable financial agencies to support their production (70.50%), poor capital base for farming (70.00%) and non-availability of loan to support farming (69.50%). According to FAO (2001) large investment costs may discourage adoption of technology. It was estimated that one hectare of sawah field will require about ₦435000 ($3000) for development. Also power tiller set used for land preparation on sawah field cost between ₦725000- ₦1015000 ($5000-7000) which is a high investment which the farmers cannot afford as revealed by the farmers in the course of this research . Power tiller is a multipurpose hand tractor designed primarily for rotary tilling and other operations on the farm. Getting loans and other financial incentives will definitely improve their scale of production (Ademiluyi et al. 2008).

The major information and training constraints faced by the farmers are lack of access to extension services (45.50%) and lack of technical knowledge of sawah (40.90%) especially water management. Technology generated, tried and proved useful but did not get to the end users is less beneficial. Both the technology generation system of the innovation, dissemination system (extension agents) and the farmers are needed for the effective utilization of an innovation. The farmer must know that the technology exists; he must know that the technology is beneficial; and he must know how to use it effectively. External sources of information, such as extension workers, may be particularly important for the adoption of new technologies. Therefore, the identification and use of appropriate communication channels is important (Onasanya et al. 2006). Lack of access to information and extension services by farmers would hinder adoption (FAO 2001).

A number of technical and mechanical constraints confronted sawah farmers. These include: non availability of power tillers (79.50%) for land preparation activities, lack of skill for land and site selection (73.90%), and complexity of water management (63.60%). Farmers faced severe challenges getting power tillers for cultivation and access to fertilizers during the cropping season. Farmers are also confronted with lack of processing facilities hence they rely on locally made drums for threshing of paddy and travel long distances to mill paddy rice. Power tiller is the only power-driven tool that is effectively used for sawah activities currently in Nigeria. It can be used for puddling, levelling, and transportation and can also be used as a power source for stationary machines for threshing and milling (Ademiluyi et al. 2008).

Table 1: Constraints faced by Sawah farmers (N=124)

Constraints	Very severe (%)	Severe (%)	Not severe (%)	Mean
Land acquisition and land tenure :				
• Accessibility	10.20	31.80	58.00	
• Availability	2.30	14.80	83.00	
• Fertility	76.10	12.50	11.40	
• Affordability	0.00	2.30	97.70	14.61
• Poor road network	87.50	2.30	10.20	
• Topography	84.10	2.30	13.60	
• Land conflict	5.00	15.00	80.00	
• Land fragmentation	13.60	47.70	38.60	
Production and on-farm constraints				
• Flood	48.90	39.80	11.40	
• Drought	2.30	42.00	55.70	16.53
• Weed	1.10	37.50	61.40	
• Diseases and pest invasion	0.00	37.50	62.50	
• Water management	86.10	11.60	2.30	
• Labour	3.40	83.00	13.60	

Marketing and economic Constraints				
• Lack of proper market facilities	34.10	36.40	29.50	
• High fluctuation in market prices	35.20	30.70	34.10	
• Lack of export marketing in the area	29.50	25.00	45.50	
• Glut during harvest	23.90	8.00	68.20	19.92
• Small Scale of production	58.00	9.10	33.00	
• Lack of capital	70.00	0.50	29.50	
• Non-availability of loans	69.50	2.50	28.00	
• Lack of finance agencies	70.50	0.00	29.50	
Input				
• Poor varieties of seeds	44.30	46.60	9.10	
• More requirement of fertilizers and manure	54.50	36.40	9.10	
• Unavailability of chemicals for weed and pest control	46.60	43.20	10.20	18.23
• Labour constraints	15.90	34.10	50.00	
• Lack of processing facility	34.10	60.20	5.70	
• Power tiller	88.60	10.20	1.10	
• High cost of inputs	51.10	45.50	3.40	

Table 1 continued on next page

Table 1 continued from previous page

Information and Training				
• Lack of information needed	15.90	68.20	15.90	
• Lack of extension and advice on sawah technology	45.50	44.30	10.20	16.85
• Lack of practical farm demonstration	11.40	12.50	76.10	
• Lack of training on sawah technology	34.10	61.40	4.50	
• Lack of technical knowledge and skill of sawah	40.90	46.60	12.50	
Technology and Mechanisation				
• Non availability of Power tiller	79.50	6.80	13.60	
• Unavailability of technical guidance on the use of Power tiller	45.50	25.00	29.5	
• Lack of skill for seed and site				

selection				
	73.90	14.80	11.40	
• Lack of knowledge and skill about weed management	55.70	35.20	9.10	27.80
• Power tiller operation for puddling and maintenance	59.10	11.40	29.50	
• Lack of knowledge and skill about bunding	33.0	13.60	53.40	
• Dyke construction	13.60	15.90	70.50	
• Complexity of water management	63.60	19.30	17.00	

Farmers' attitude and perception of sawah technology: The result of the study however shows that farmers have positive attitude toward sawah technology. As shown in Table 2, there was no resistance from the farmers to adopt sawah technology and they have positive attitude toward it. Attitude and perceptions of the farmer who are the end users of the various activities that makes up the sawah package must be taking into account. Wossink and Boonsaeng (2003) opined that perception and knowledge is crucial for successful research

Farmers still use manual system of rice processing.

and development strategies and that many promising agricultural policies have failed because they were inappropriate to farmers need and perception. Farmers' attitudes and perception are of crucial importance to successful development strategies. Many promising agricultural innovations and supporting policies have failed because they were inappropriate to farmers' needs. It must be noted that the perceived risk of technologies may serve as a barrier to adoption. Majority of the farmers believe that sawah pose no risk to their production. Also, farmers believe that sawah rice production is profitable and worth adopting.

Table 2: Farmers' attitude and perception of sawah technology

Variables	Agree (%)	Indifferent (%)	Disagree (%)	Mean
• Perception of risk	10.20	1.10	88.60	
• Perception of low profitability	10.20	10.20	79.50	
• Non-perception of necessity for suitable technology	0.00	26.10	73.90	7.01
• Impact of beliefs and traditions	0.00	2.30	97.70	
• Negative attitude towards innovation	0.00	14.80	85.20	
• Farmers resistant to change	0.00	5.70	94.30	

Correlation analysis between Study Variables: Table 3 shows the inter-correlation between constraints to sawah technology among the farmers. There are a range of constraints that influenced the rate of adoption of innovations. The results revealed that the existence of one constraint influenced the other. Land tenure constraints were related to production constraints ($r=0.52$; $p<0.01$), input ($r=0.60$; $p<0.01$), and technical constraints ($r=0.42$; $p<0.01$). This implied that as the constraints of land tenure persist, farmers are bound to be confronted with constraints related to production, inputs and technology. Also, information constraints were related to economic ($r=0.38$; $p<0.01$), input ($r=0.70$; $p<0.01$), and production related constraints ($r=0.62$; $p<0.01$). This implies that information constraints influenced the economic, input and production related constraints of the farmers.

Furthermore, farm size of the farmers was negatively related to land acquisition and tenure related constraints ($r=-0.52$; $p<0.01$). This implies that as much as land tenure problem persists, farmers' farm size will continue to reduce. Land tenure in the study area is predominantly by inheritance (Fu et al., 2009). In this tenural system, farm land belonging to a family is shared between all the family members. As the population increases and the distribution continues from one generation to another, land fragmentation occurs. This in turn affects the size of land available to individual member of the family.

Farm size of the farmers was negatively related to production and on-farm related constraints ($r=-0.46$; $p<0.01$). The implication of this is that farm size is negatively affected by the persistence of production and on-farm related constraints. That is, due to production constraints, farmer may not be able to expand the scale of his production. A farmer facing challenges of providing farm inputs and management of the farm in terms of resources for weeding, diseases and pest control, water control and labour for farm operations may not be able to increase the size of his farm. Farm size is negatively related to economic and market and technological constraints. Farmers with limited resources such as input, labour, and machine may be constrained and may not be able to increase the size of his plot and hence have limited yield. However, household size is positively related to the farm size of the farmers. This implies that as the household increases, the farm size also increases. However, this must be subject to availability of land and other farm inputs. This may be due to the fact that the relative increase in the household size could serve as a source of farm labour.

Further, there was a negative significant relationship between input constraints and yield of farmers ($r=-0.22$; $p<0.05$). The non availability of inputs reduced the farmers yield. Adoption of sawah technology depends on the availability of inputs such as power tillers, fertilizers, improved rice seeds and other farm inputs. Availability of these inputs will influence the level of adoption of sawah technology among the farmers and their farm output. The more available farm resources are, the greater the level of adoption and expansion of sawah technology and the non availability of this resources, pose serious threat to the famers rate of adoption. According to Mupangwa (1994) and Mapiye et al. (2006) adoption is hampered by high cost and low availability of farm inputs. The unavailability of appropriate harvest and post harvest equipment is a major constraint. Farmers rely on locally made equipments for threshing and milling of paddy. Access to improved varieties and good quality seed was cited by farmers as a major constraint.

Financial constraints have been reported by respondents as an important barrier to the adoption of changed management practices (Cary et al. 2002; Greiner et al. 2003; Byron et al. 2004). For example, Greiner et al. (2003) found that operational and financial constraints are perceived as the most important impediments to the adoption of natural resource management activities or changed practices. If the level of income available to invest in new practices is insufficient, farmers are unlikely to invest, constraining the adoption of more sustainable technologies (Webb 2004).

Table 3: Correlation matrix of the study variables (N = 124)

Variables	1	2	3	4	5	6	7	8	9	10	11	12
1. Land acquisition and tenure	1.00											
2. Production and on farm constraint	0.52**	1.00										
3. Economic market constraints	0.18	0.38**	1.00									
4. Input availability related constraints	0.60**	0.70**	0.40**	1.00								
5. Information and training constraints	0.15	0.62**	0.20	0.54**	1.00							
6. Technological and scientific constraints	0.42**	0.02	0.54**	0.61**	0.38**	1.00						
7. Attitude and perception constraints	0.01	0.11	0.07	0.10	0.16	0.17	1.00					
8. Age	0.16	0.09	0.02	0.12	0.11	0.14	0.16	1.00				
9. Educational Level	0.37**	0.09	-0.29**	-0.41**	-0.25**	-0.39**	0.03	0.51**	1.00			
10. Household size	0.43**	0.09	0.17	0.06	0.25*	0.13	0.04	0.48**	0. 13	1.00		
11. Farm size	-0.52**	-0.46**	-0.47**	-0.35**	0.14	0.33**	0.13	0.11	0.22*	0.32**	1.00	
12. Yield	-0.41**	-0.18	-0.45**	-0.22*	-0.12	-0.46**	0.11	0.36**	0.53**	0.34**	0.91**	1.00

* Significant at $P < 0.05$; ** Significant at $P < 0.01$. Source: Field survey

***Regression analysis showing the relationship between Yield and constraints**:* The regression model used to determine the relationships between the yield and constraints as predictor variables is shown in the equation below and the result shown in Table 4.

$$Y = 12556.16 - 0.34 X_1 - 0.13 X_2 + 0.13 X_3 + 0.05 X_4 - 0.02 X_5 - 0.429 X_6 + 0.22 X_7 - 0.27 X_8$$

The yield is inversely related to land acquisition and land tenure constraints ($\beta = -0.34$; $p < 0.05$). This showed that lack of access to farm land has negative effect on yield. In most cases, land fragmentation, due to tenure system practiced limits the availability of land for sawah-based rice production. Sakurai (2005) reported that investment in water supply canals is influenced by land tenure security and that the canals enhanced yield. Farmers who have no land for production are likely to spend money that was supposed to be used for the procurement of inputs and machines for the payment of land rent. Emanating from the discussion with the respondents during the course of this study, farmers pay as much as ₦12000 ($83) annually as rent for an acre of land. This may increase with increase in the rate of adoption of sawah technology in Nigeria.

Yield of sawah was also inversely related to technological constraint ($\beta = -0.43$; $p < 0.01$). The non availability of power tillers, unavailability of technical guidance on the use of power tiller, lack of skill for seed and site selection, lack of knowledge and skill about weed management, power tiller operation for puddling and maintenance and lack of knowledge and skill about bunding have negative effects on the yield of farmers. However, there were positive relationships between farmers' yield and attitudes to sawah technology ($\beta = 0.22$; $p < 0.05$). This implies that farmers' positive attitude towards sawah technology has a positive effect on his commitment to sawah and timeliness of operations hence increases his yield. This may be as a result of higher yield, better water and weed control qualities of sawah as reported by Fu et al. (2009). Addressing the farmers' constraints will require a holistic approach in which all the constraints identified are addressed to improve on sawah development among the farmers.

Table 4: Regression analysis showing the relationship between Yield and constraints (N=124)

Variables	Standardised coefficients *(b)*	*t*-value	*p*	Decision at p-value = 0.05 and 0.1
Land acquisition and tenure	-0.34	-2.34	0.02	Significant
Production and on-farm constraint	-0.13	-1.06	0.30	Not significant
Economic market constraints	0.13	0.94	0.35	Not significant
Input availability related constraints	0.05	0.34	0.74	Not significant
Information and training constraints	-0.02	-0.18	0.86	Not significant
Technological and scientific constraints	-0.429	-3.597	0.01	Significant
Attitude and perception constraints	0.22	1.68	0.05	Significant
Total constraints	-0.27	-2.22	0.03	Significant

R = 0.46, $R^2 = 0.22$, Adjusted $R^2 = 0.13$, F = 2.44,

6.5.Conclusion

The discussions highlight the important constraints that must be addressed in order to improve the adoption of sawah system of rice production in Nigeria. The constraints, covering a wide array of issues included land acquisition and tenure, economic, information, communication and training, technical and mechanical constraints. The problems were found to be interwoven and influence each other. As constraints of land tenure persist, farmers are bound to be confronted with production, inputs and technology constraints. Lack of adequate information was found to be related to economic, input and production constraints of the farmers. Addressing these problems will lead to increase in the rate of adoption of sawah rice production technology and ultimately rice productivity in Nigeria.

6.6.Recommendations

The study recommends a reform on land by the government with appropriate legislation that will ensure effective, simplified, sustainable and successful land administration in Nigeria and give access and security on land for farmer willing to use land for agriculture especially sawah development. In addressing the credit challenge faced by sawah farmers, government should strengthen the financial base of informal institutions such as the cooperative societies in the rural communities by providing credit subsidies to them. This will encourage them to continue to offer credit delivery to rural farmers. Effort should also be made by stakeholders in rural credit schemes to increase the establishment of informal institutions in the rural areas. Government should train and deploy more extension agents to the areas where they can help train the farmers on how to best use sawah technology to improve on their rice production and for effective information communication. This can be achieved by organising on-the-job trainings for the extension agents in order to effectively train the farmers all the rudiment of sawah technology to bridge the training and information gap of the farmers. Cooperative farming should be encouraged among the farmers in order to be able to acquire farm input such as power tiller that is out of reach of individual farmer.

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CHAPTER 6

Training and Sawah Development

This chapter examined the training need of farmers and extension agents for sawah development. Section 1 identified knowledge and training needs of farmers adopting sawah rice production technology in Nigeria while section 2 focused on assessment of professional competencies and training need of extension agents for sustainable sawah development in Nigeria.

Knowledge and Training Needs of Farmers Adopting Sawah Rice Production Technology in Nigeria

6.1.1. Introduction

Agriculture remains the main stake of the economy in most developing countries all over the world. Millions of farmers rely on land, which is too small and too poor to sustain the living of their families, but still they have to make ends meet on that land. In West Africa, the area of unplanted land resulting from desertification and urbanization grew in the last three decades by 9 million hectares, which is higher than any other part of the world (Hirose and Wakatsuki, 2002). During this period, agricultural productivity in West Africa has not improved but the population has continued to grow, combined with endless destruction of forests and farm land. Population growth has resulted in environmental disruption which reduced food productivity and promoted the destruction of the environment (Hirose and Wakatsuki, 2002). In Nigeria various interventions have been implemented to improve food production and farmers income through the provision of agricultural infrastructure, inputs and effective extension work such as National Accelerated Food Production Project(NAFPP), National Fadama Development Project (NFDP), National Economic Empowerment and Development (NEEDS) National Special Programme for Food Security (NSPFS) (Jibowo, 2005) and National Rice Development Strategy (NRDS) aimed at increasing rice production in Nigeria. However the successes of these interventions still remain invisible.

The impact of rice production, which contributed to a substantial reduction in poverty and the launching of broader economic growth in many Asian countries through a combination of biotechnology as manifested in the use of high yielding varieties of rice and sawah eco-technology as a tool for Green Revolution (Otsuka and Kijima, 2010) has not been optimally felt in Nigerian. This may be as a result of lack of knowledge, unfavourable policy environment, poverty, lack of training, and the method of training without taking into consideration the training need of each farmer for effective utilization of technology. Most farmers need specific training and information in order to effectively use sawah technology and thus improve their production. Sawah refers to levelled rice field surrounded by banks with inlet and outlet for irrigation and drainage. The basic elements of sawah system include improved irrigated rice basins, seedbed preparation, transplanting and spacing of seedlings, fertilizer application and most importantly, appropriate water management (Padoch, et al., 1998; Wakatsuki and Buri, 2008). Sawah rice production system was introduced to the inland valley of Nigeria because it can overcome soil fertility problems through enhancing the geological fertilization process, conserving water resources, and the high performance multi-functionality of the sawah type wetlands (Oladele and Wakatsuki, 2008). In order to realize green revolution in Sub-Saharan Africa, it is essential to improve rice-growing environment by promoting lowland sawah eco-technology (Wakatsuki, 2008). Fashola *et al.* (2006) also noted that the sawah system offers the best option for overcoming the constraints of rice production in Nigeria, namely poor soil fertility, poor water management and poor varieties. It is because the sawah system utilizes the inland valleys which are reported to be high in fertility and through appropriate water management fertility can be sustained and enhanced for rice production.

Training farmers for development is one of the numerous activities that need to be carried out to sustain production of food and to enhance self-sufficiency in food production in the developing world. Training is mostly directed at improving the ability of individual to do their vocation more effectively and efficiently (Farinde and Ajayi, 2005). Generally, it involves acquiring information and developing abilities or attitudes, which will result in greater competence in the performance of a work. On the necessity of training and active participation for success in any rural development endeavour, Bari (1987) noted that for effective rural development, participation of rural people in the development process is essential. But people cannot participate unless they have been motivated or made aware about the changes they need for their welfare. As such training is playing a vital role to make the rural people aware and act as subjects in the development process (Bari, 1987). Mengistu (2009) highlighted the contributions of training to agricultural development as providing farmers with the basic skills, improving rationality, increasing inquisitiveness and thereby improves receptivity for new ideas, opportunities, and methods and changing values and aspirations, and there by strengthens the will to economize and facilitates the adoption of new techniques.

Ajayi (1995) defined training as the acquisition of the best way of utilizing knowledge and skill. Goldstein (1993) defines training as a systematic acquisition of skills, rules, concepts or attitudes that results in improved performance in another environment. Training is a circular process that begins with needs identification, implementation and ends with evaluation of the training. A change or deficiency in any step of the training process affect the whole system and therefore, it is important for a trainer to have a clear understanding about all phases and steps of the training process; planning, implementation and evaluation. Owona et al. (2010) defined training need as skill, knowledge and attitude an individual requires in order to overcome problem as well as to avoid creating problem situation. Training need to Adesoji et al. (2006) is the different between what is and what ought to be. This means that for training to be needed, a gap or vacuum must be presented which needs to be filled. Farinde and Ajayi (2005) stated that training needs exists anytime an actual condition differs from a desirable condition in the human or people aspect of organizational performances or more specifically when a change in present knowledge, skill and attitude can bring out the desired performance.

Past Studies had earlier shown the need to determine the training needs of farmers. Adesoji et al (2006) assessed the training of Fadama farmers for future agricultural extension work development in Osun state, Nigeria. Farinde and Ajayi (2005) investigated training needs of women farmers in livestock production in Oyo state, Nigeria; Ajayi and Okoedo-Okojie (2008) assessed the perceived training needs of cassava farmers in Ovia north east local government area of Edo state, Nigeria, Ajayi et al. (2003) assessed the women farmers training need and their correlates for effective extension programme and poverty reduction in Oyo state, Nigeria. Similarly, Al – Shadiadeh, (2007) carried out a descriptive study of the training needs for men and women farmers in semi desert areas of South Jordan. All of these studies identified the training need as important in adoption of technology among their respondents.

Identification of training needs of the sawah farmers is a crucial element in sawah development process. Success of any training programme carried out depends greatly on the correct identification of needs. The needs assessment for training is the basis for extension process and its activities. All interventions that do not take these needs in consideration tended to be wasting valuable resources (Al – Shadiadeh, 2007). Hence a study of the training needs of farmers is essential for the successful dissemination and adoption of sawah technology. This study examined the socio-economic and farming characteristics of farmers, cropping pattern, information sources, knowledge and the training needs of the sawah farmers as they affect sawah development.

6.6.2. Method

Descriptive statistics were used to analyze the socio-economic and farming characteristics of the farmers. Correlation analysis was employed to determine the interrelationships between the study variables and regression analysis was used to determine the relationships between training needs and other study variables.

6.1.3. Result and Discussion

Cropping pattern and use of sawah technology among respondents: The result of the study shows that majority (84.10%) of the farmers practiced mono cropping. They grow only rice on the sawah field. However, discussion with the farmers revealed that the farmers plants vegetable on the field during the dry season which they harvest before the following rice planting season. As part of the sawah technology package, all the farmers (100%) raised their rice in the nursery before transplant as against the old method of broadcasting. The farmers however complained about the stress of transplanting with hand in which they hope that can be solved by using a rice machine (transplanter) for transplanting. All the farmers bund their sawah fields which helps in water management and effective in nutrient use and management in the soil. The result further shows that 62.50% of the farmers puddle their fields. Non availability of power tiller for use in the puddling restrains other farmers. It was also revealed that the average yield per hectare would have been increased if all the farmers have access to power tiller at the right time. This also reflect on the fact that an appreciable number of farmers (69.50%) and (79.70%) of the farmers could not level and smoothen their sawah field. Levelling and smoothening improve water and nutrient distribution in the sawah basin thereby increasing the yield of rice.

Table 1: Cropping pattern and use of sawah technology among respondents

Variable	Frequencies	Percentage
Cropping pattern		
a. Mono cropping	104	84.10
b. Mixed cropping	20	15.90
Nursery preparation for sawah	124	100.00
Bunding of the field	124	100.00
Puddling of field	78	62.50
Levelling of field after puddling	37	29.50
Smoothening after levelling	25	20.30

Knowledge of sawah technology among the respondents: Identification of the knowledge level of the farmers will help in determining where trainings are necessary to be conducted to the farmers to improve sawah development in Nigeria. The result of the study shows that farmers have average knowledge of sawah. Majority (86.40%) of the farmers correctly identify the first operation carried out in sawah development. Majority (96.60%) of the farmers identify the place where seedlings are grown before transplanting to the sawah field as nursery and the type of land used for sawah as lowland. However, the farmers could not correctly explain the process of moving soils on the basin for levelling. This also affirms that most of the farmers have not been levelling their field. In addition, majority (75.00%) of the farmers could not explain the point of introducing water into the sawah basin as the inlet and drainage as outlet. Effective water management is an important component of sawah and determines to a greater extent the success of sawah. On the sequence of operation carried out in sawah field development, majority of the farmers scored above the average indicating that they have some knowledge of sawah. This may not be far from the fact that they have be on rice production for long time and this goes with an adage which says "experience is the best teacher".

Table 2: Knowledge of sawah technology among the respondents.

Variables	Frequencies	Percentage
1. Identification of first operation in sawah technology	107	86.40
2. Levelling of Plot	70	56.80
3. Flooding of plot	78	63.60
4. Nursery	120	96.60
5. Lowland/Fadama	101	81.80
6. Water Inlet and outlet	31	25.00
7. Sequence of operations		
1-3	7	5.70
4-6	73	59.00
7-9	42	34.10
>9	1	1.10

Information source about sawah among respondents: Table 3 shows the sources of information about sawah among the farmers. Majority of the farmers got information about sawah from sawah contact farmers (98.23 %) and their colleagues (79.03%) in rice farming in their locality. These variables indicate the intensity of contacts with contact farmers and other farmers. Farmers who do not have contacts with extension agents may still be informed about new technologies by their colleagues. Other got their information from their village head (55.32%), group meeting of the farmers group (39.52%), training attended (10.16%), radio (2.26%), researchers (2.26%), and the extension agent (1.13%).

Table 3: Information source about sawah among respondents

Sources	*Frequency	Percentage
Contact farmers	122	98.23
Farmers	98	79.03
Village head	69	55.32
Group meetings	49	39.52
Training attended	13	10.16
Radio	3	2.26
Researchers	3	2.26
Extension agent	1	1.13

*Multiple responses provided.

Training needs among the respondents: Table 4 shows the training needs of the sawah farmers in Nigeria in order of priority. Water management (95.50%), power tiller operation and management (93.20%), and sawah layout and design (88.60%) are the most important areas where farmers need training. This may be due to the fact that an effective water management is the 'back bone' of sawah development. Sawah is a levelled rice field surrounded by banks with inlet and outlet for irrigation and drainage. Improved irrigated rice basin is a basic element of sawah system development (Oladele and Wakatsuki, 2008). Therefore there is need for the farmers to be acquitted with the basic training on water management in sawah development. Surface levelling and smoothening (74.60%) and nursery management (74.60%) are other areas of training need. Harvesting, processing and adding value to produce (65.30%) are other areas of training need. Farmers still rely on traditional methods of harvesting and processing using drums. Farmers sell their yield during harvest glut in the market which affects the price system. Fertilizer usage and nutrient management (61.40%) is also one of the areas of training need. Sawah fertilizer usage is a critical aspect of the development process. Sawah system encouraged not only the growth of rice plant but also the growth of various aquatic algae and other aerobic and anaerobic microbes, which increase nitrogen fixation in the sawah system through increase of photosynthesis as functional wetlands. This eventually increased the yield of sawah rice (Kyuma, 2004; Greenland, 1997). If in an attempt to improve the fertility of the soil, excess fertilizer is applied, it will be in disadvantage to the crops. Disease and pest control (54.00%) weed control (52.00%) and purchase of farm inputs for sawah development (42.00%) are the other areas where training is needed by the farmers.

Table 4: Areas of training needs among the respondents in order of priority.

Training Areas	Frequency	*Percentage
1. Irrigation Technique	118	95.50
2.Power tiller operation	116	93.20
3.Sawah layout	110	88.60
4.Surface levelling	93	74.60
5.Nursery management	93	74.60
6.Harvesting	81	65.30
7.Processing	81	65.30
8.Fertilizer usage	76	61.40
9.Disease and pest control	67	54.00

10.Weed control	64	52.00
11.Purchase of farm inputs	52	42.00

*Multiple responses provided.

Types of training respondents are willing to attend: Table 5 shows the type of training the farmers are willing to attend. For training to meet the aspirations of farmers, their status and conditions must be taken into consideration. The training types farmers are willing to attend in order of preference are on-the-job training (OJT) (92.70%), field visitation and observation (58.00%) and farmer field day (28.23%). On-the-job training (OJT) is one of the best training methods because it is planned, organized, and conducted at the farmers' field. On-the-job training will generally be the primary method used for broadening farmer's skills and increasing productivity. It is particularly appropriate for developing proficiency skills unique to farmers' job. However, morale and productivity will be high in organizing and conducting an on-the-job training as its success is determined by how it is planned. Visiting of model

Operation of power tiller requires skill that must be mastered by farmer. (Photo number 2 credit to Prof Wakatsuki) sawah site by farmers can also help as a source of training. Farmers' regular visit to model sites around their field can go a long way to improve on their knowledge of sawah. During visits, questions on the grey areas can be asked from the sawah leader thereby improving their knowledge. In addition, attending farmers, field day in sites of successful adoption by farmers can improve their knowledge of sawah. Farmers' field days (FFD) provides an opportunity for hands-on learning. Farmers from across various locations have a chance to learn practical skills, get answers to their questions, and meet other like-minded folks during Farmers' field days (FFD)

Table 5: Types training respondents are willing to attend

Training types	*Frequency	Percentage
On the job training(OJT)	115	92.70
Field visitation and observation	72	58.00
Farmers Field days (FFD)	35	28.23

*Multiple responses provided.

Relationship between the study variables: Table 6 shows the detailed analysis with correlation matrix significant at 0.05 and 0.01. The result of the study shows that there was a significant($r=-0.54$, $p < 0.01$) but negative correlation between the training needs of the farmers and years of experience in rice farming. This implies that as the years of experience increases, the training needs reduce. Also, there is a significant ($r=-0.26$, $p < 0.05$) relationship but negative between training needs and years of experience in sawah rice

Cross section of farmers and trainees during NAGOYA training in Bida Nigeria. (Photo from Prof Wakatsuki) production. This implies that as the years of experience in sawah increases, training needs decrease. These results agree with the saying that experience is the best teacher. The years of experience gathered in rice production and sawah production over the years may lower their training needs in some aspect of sawah technology. The experienced sawah farmers might have come across some problems and those they were able to solve will add to their experience which they can share among their peers. The in experience farmers will show higher affinity for training and willingness to participate in trainings. The result of this study is supported by the findings of Adesoji *et al.* (2006). There is also a significant($r=-0.23$, $p < 0.05$) but negative correlation between knowledge of the farmers and training needs. The implication of this is that as the knowledge of sawah increases among the farmers, training needs decrease. Correlation analysis also show that there is a significant positive relationship between the years of experience in sawah rice production and age ($r=0.36$, $p < 0.01$), educational level ($r=0.37$, $p < 0.01$), years of experience in rice production($r=0.49$, $p < 0.01$), and the yield of farmers. This implies that as the age, educational level and experience in rice production increase, the experience in sawah also increases. There also exist a positive significant relationship between sawah rice experience and the yield of sawah. The implication of this is that, as the experience gathered by farmers increase, their yield also increases. A positive significant relationship exist between yield of sawah rice and household size ($r=0.25$, $p < 0.05$), farm size ($r=0.90$, $p < 0.01$) and income($r=0.41$, $p < 0.01$) of the farmers. This implies that increase in farmers' household size, farm size and income of farmers will increase the yield of the farmers. There is also a significant between information sources ($r=0.60$, $p < 0.01$) and the knowledge of sawah among the farmers. This implies that as the farmers get more information, their knowledge will be improved. Also there is significant positive relationship between information sources (r=0.25, p < 0.05) and experience in sawah rice production.

Table 6: Correlation matrix showing correlation between study variables

	1	2	3	4	5	6	7	8	9	10	11	12
1.Age	1.00											
2.Educational Level	0.515**	1.00										
3.Household size	0.548**	0.214	1.00									
4.Farm size	0.075	0.008	0.251*	1.00								
5.Income	0.378**	0.248*	0.364**	0.418**	1.00							
6.Years of experience in rice production	0.896**	0.667**	0.490**	0.001	0.344**	1.00						
7.Yield of Sawah rice	0.118	0.023	0.245*	0.901**	0.414**	0.041	1.00					
8.Years of experience in Sawah rice Production	0.361**	0.378**	0.385**	0.205	0.043	0.492**	0.246*	1.00				
9.Distance from farm to house	0.067	0.123	0.111	0.053	0.043	0.131	0.128	0.111	1.00			
10.Knowledge of sawah	0.040	0.267*	0.110	0.057	0.078	0.096	0.012	0.244*	0.012	1.00		
11.Information Source	0.017	0.222	0.059	0.126	0.030	0.123	0.114	0.250*	0.013	0.596**	1.00	
12. Training needs.	0.045	0.079	0.104	0.074	0.064	-0.542**	0.042	-0.261*	0.057	-0.229*	0.03	1.00

Regression analysis showing relationship between training needs and other study variables: Table 7 shows that regression there were negative relationships between training needs of farmers and age, (β=-0.540), years of experience in sawah, (β =-0.534), training attended (β =-0.182) knowledge of sawah, (β =-0.044). The result implies that the older the farmers are the less their training needs. This may be as a result of resistance and adamant to change by older farmers as the younger farmers may want to learn more. This agrees with the findings of Adesoji, et al (2006) and Ajayi, (1995). In addition, experience the older farmers have gathered in rice production may also stand as an obstacle for them to be interested in other train in rice production. The regression coefficient of Household size (β =0.708) and Farm size (β =0.621) were positive. This implies that the larger the household size the more the need for training and the higher the farm size the more the training required.

With increase in the household size, there may be need to increase the size of the land cultivated, and in an attempt to increase the size of the farm, there will be need to ensure a success and high yield from the farm, so there will be more need for the farmer to be searching for a mean of improving their knowledge through trainings. Also, as the farm size increases, farmer will be desired to maximise the profit from investment thereby desire to have trainings on the new ways of doing things therefore will desire to have training.

Table 7: Result of regression analysis showing relationship between study variables.

Variables	B	SE	Std β	t-ratio	Sig
Constant	2.76	1.23		2.24	0.03
Age	-1.48	0.61	-0.540	-2.41	0.02
Sex	0.20	0.31	0.104	0.63	0.53
Educational Level	0.00	0.11	0.001	0.00	0.99
Marital Status	0.16	0.58	0.056	0.28	0.78
Household size	1.44	0.50	0.708	2.88	0.01
Farm size	1.37	0.62	0.621	2.20	0.03
Experience in Sawah	-0.84	0.45	0.534	-1.87	0.07
Income	0.12	0.08	0.232	1.38	0.18
Training Attended	-0.08	0.07	-0.182	-1.08	0.29
Areas of training	-0.05	0.11	-0.070	-0.43	0.67
Information Sources	0.02	0.04	0.090	0.55	0.58
Knowledge of Sawah	-0.08	0.33	-0.044	-0.26	0.80
Training constraints	-1.29	0.85	-0.39	-1.52	0.14

R=0.576, R^2=0.332, Adjusted R^2= 0.135, F= 1.682, Standard Error of Estimate= 0.88.

6.1.4. Conclusions and recommendations

Based on the findings of the study, married farmers are engaged in sawah rice production and have Quranic education. Also, few old farmers are engaged in sawah farming. Majority of sawah farmers practiced mono cropping and nurse their rice and bund their sawah field. The major sources of information about sawah are contact farmers and other rice farmers. The areas of priority for training are water management, power tiller operation and management, and sawah plot layout. Farmers are willing to attend on-the-job training if given the opportunity. Base on the findings, the study recommends that on-the-job training should be organised for the farmers. Also, extension agents in the areas where sawah has been disseminated should be train on the rudiments of sawah development to serve as the change agent in their areas and assist the trained contact farmers and to be able to train other farmers since they are close to these farmers and the farmers are already use to them. Training content must be in line with the priority of the farmers in areas of water management, power tiller operation and management and in plot layout and design. Also, when organising training, the age, location, knowledge and experience of the farmers should be considered.

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Assessment of Professional Competencies and Training Need of Extension Agents for Sustainable Sawah Development in Nigeria.

6.2.1. Introduction

The adoption of new technologies is often influenced by the farmer's contact with extension services, since extension agents provide information and technical advice to the farmers. Agricultural transformation and increased productivity is greatly influenced by the effectiveness of agricultural extension services (Njoku, 1990). According to Omoregbee and Ajayi (2009) extension as an educational input can make an important contribution to sustainable agricultural production and rural development. The efficiencies in the development and delivery of relevant information and assistance from extension systems determine to a greater extent the level of adoption of any innovation by the farmers. Obinne and Anyanwu (1991) and Rogers (1995) have argued that successful adoption of improved farming technologies is predicated upon rural farmers acquiring the required knowledge and understanding of these technologies, a process most effectively accomplished by the agricultural extension service. Although, other factors such as profitability of the technology, perceptions of technology-specific characteristics and emerging economic constraints may influence successful adoption of improved farming technologies, the role of extension in providing the required knowledge cannot be over emphasised.

For farmers to adopt a new agricultural technology, they must be aware of the technology, have valid and up-to-date information on the technology, the applicability of the technology to their farming system and receive the technical assistance necessary to use the technology (Asiabaka *et al*., 2001). This can be achieved from extension agents with vast knowledge about the technology in question (Ajayi and Aphunu, 2007). Agricultural extension agents play a significant role in extension services (Tladi, 2004). The success or failure of any extension programme is dependent on effective performance of extension agents. Extension staff training has been increasingly valued as a crucial issue in implementing extension programmes (Arokoyo, 1990; Baradough, 1993). However, for agents to help with sustainable agricultural practices they must first understand sustainable agricultural concepts (Agunga, 1995). Assessing educational and training needs of extension agents is an important element in extension service and seen as a critical factor in the success of the extension organization. According to Buford, *et al* (1995), as extension agents face the challenge of learning new skills to maintain their proficiency or become qualified for their job, the importance of an effective training programme becomes evident and to ensure extension agents are well trained, there exists a need to determine training needs to increase agent capabilities. Similarly Chizari, *et al*. (1998) noted that extension will be seriously limited in its ability to plan and execute effective educational programmes and other technology transfer activities, without an adequate number of well-trained agents. If extension agents are not convinced of the value of an innovation, how can they be expected to educate farmers?

Yondeowei and Kwarteng (2006) defined training need as the difference between the required level of individual competence and present level of competence. Farinde and Ajayi (2005) stated that training needs exist anytime an actual condition differs from a desirable condition in human aspect of organizational performance or more specifically when a change in present knowledge, skill and attitude can bring out the desired performance. Adesoji *et al*. (2006) defined training need as the difference between what is and what ought to be. This means that for training to be needed, a gap or vacuum must be presented which needs to be filled.

Sawah system of rice production was introduced to inland valleys of Nigeria in order to overcome constraints faced by farmers in rice production. According to Fashola *et al* (2008) sawah technology is a response to overcome major constraints faced by rice farmers in Nigeria which include poor soil fertility, poor water management and poor varieties. Sawah has contributed to a substantial reduction in poverty and the launching of broader economic growth in many Asian countries through improved cereal varieties, fertilizers, irrigation, and modern pest control methods lay at the heart of the Green Revolution (GR) (Otsuka and Kijima, 2010). Sawah refers to levelled rice field surrounded by banks with inlet and outlet for irrigation and drainage. The basic elements of sawah system include improved irrigated rice basins, seedbed preparation, transplanting and spacing of seedlings, fertilizer application and most importantly appropriate water management. The sawah based rice farming can overcome soil fertility problems through the enhancement of the geological fertilization process, conserving water resources and the high performance multi- functionality of the sawah type wetlands (Wakatsuki and Buri, 2008).

If agricultural extension agents are to improve in their effectiveness in the dissemination of sawah technology, they must receive adequate training according to their needs. A training need assessment is therefore essential. However, no research has been carried out to identify the training needs of extension agents for a sustainable sawah development in Nigeria. Once the relative needs are determined and an appropriate listing of priorities is established, the available resources could be utilized and made productive. According to Onazi (1984) one of the main factors limiting the development of effective training programmes for extension workers in developing countries is the inadequacy of information on their training needs. For the adoption of sawah technology to improve, agricultural extension agents are expected to know more about the technology so as to meet the extension service demands of a diverse farmer population. Adequate skills acquired by extension agents will result in more adoption by the farmers (Hoque and Usami, 2008). In the context of extension skill development, inadequate training is a common constraint for developing extension skills among the extension agents (Halim, 1991). Lack of training had also produced a negative impact on the working efficiency of extension field staff. It is important to realize that the training and information needs of extension workers include not only technical knowledge but also knowledge and skills that increase the effectiveness of delivery. Improving access to these vital extension skills will lead to better designed, delivered and supported technologies (Bell, 2004).Therefore, this study aims at assessing the professional competencies and training needs of extension agents for sustainable adoption of sawah technology in Nigeria. The specific objectives are to:

1. Identify the sources of information about sawah technology.
2. Determine the extension competencies required by the extension agents for effective dissemination of sawah technology.
3. Identify areas of training needs of the respondents on sawah technology
4. Identify respondents' preferred method of training

6.2.2. Research Methodology

Study area: The study was carried out in Nigeria. Nigeria is located in Western Africa on the Gulf of Guinea and has a total area of 923,768 km2 (356,669 sqm). Nigeria shares land borders with the Republic of Benin in the west, Chad and Cameroon in the east, and Niger in the north. Agriculture contributed 41.84% to the GDP in 2009. Nigeria has 36 states and Abuja the Federal Capital Territory (FCT). This study was carried out in five states namely Niger, Kaduna, Ondo, Kwara, Ebonyin and Abuja the FCT where sawah is being practiced.

Sampling technique and sample size: Purposive sampling technique was used to select five states namely Kaduna, Ondo, Kwara, Ebonyin, Niger and Abuja for the study due to the use of sawah technology in these areas. Twenty extension agents from the states' Agricultural Development Programme (ADP) and Abuja were randomly selected for the study to give a total of one hundred and twenty respondents. A pre-tested questionnaire was used to elicit information from the respondents. The questionnaire was designed to elicit information on the personal characteristics of the extension agents, sources of information about sawah technology, areas of training needs of the respondents on sawah technology, the professional competencies required by the extension agents for effective dissemination of sawah technology and respondents' preferred method of training.

Data analysis

The data obtained were subjected to descriptive and inferential statistics. The descriptive statistical tools used include frequency counts and percentages while regression analysis was used as inferential statistics. While the descriptive statistics form the basis for discussion of the obtained results, the regression analysis was used to establish the relationship between the training needs of extension agents and predictor variables as specified in the equation below:

$$Y = a + \beta X_1 + \beta X_2 + \beta X_3 + \beta X_4 + \beta X_5 + \beta X_6 + \beta X_7 + \beta X_8 \quad (1)$$

Where Y = Training needs; X_1 = Age; X_2 = Sex; X_3 = Marital status; X_4 = Years of experience; X_5 = Years of involvement in sawah; X_6 = Information sources; X_7 = Number of trainings attended; X_8 = attendance in previous training.

Validity and reliability

The questionnaire was subjected to face and content validity with the help of resource persons in agricultural extension. This was done in order to ensure that the study variables were appropriately and adequately captured and measured. The reliability of the data gathering instrument was conducted using test-re-test method. To this end, the questionnaire was administered to 30 extension agents randomly selected from the study population at interval of two weeks after which the responses were compared. Items that were readily responded to were ascertained okay while the ones that were too technical or ambiguous were modified to ensure the reliability and standardisation of the questionnaire.

Variable selection and measures

Dependent variable

Training needs of extension agents: Training needs of extension agents was measured by asking the extension agents to indicate the areas of sawah technology they need training in order to be able to disseminate sawah technology effectively as shown in Table 3. The areas of training needs of the respondents on sawah technology are sawah layout and design, site selection for sawah rice production, power tiller operation and management, ploughing and puddling, fertilizer usage, irrigation and water management, levelling, smoothening, weed control, disease and pest control, nursery management, purchase of farm inputs for sawah development, transplanting, harvesting and processing.

Explanatory variables

Personal characteristics of the extension agents: The personal characteristics of the extension agents identified in the study are age, sex, marital status, educational level, years of working experience, years of involvement in sawah, attendance in previous training and number of training attended.

Sources of information about sawah technology: Respondents were asked to indicate their sources of information about sawah technology. These include colleagues, journals, internet platforms, newspaper, television, radio and magazines.

Professional competencies required by the extension agents: This was measured by asking the respondents to indicate the professional competencies required for effective dissemination of sawah technology. These include conducting demonstration, communication skill, farmers training, formation of farmers' groups, farmer identification and selection of contact farmers

Preferred method of training: Respondents were asked to indicate their preferred method of training. These include on-the-job training, demonstration, field visitation and observation, workshop, group discussion and lectures.

6.2.3. Results and Discussion

Personal characteristics of extension agents: As shown in Table 7, the age of the respondents ranged between 21 and 59 years with the mean age of 39.42 years (SD = 10.34). More than half of the extension agents (58.30%) were in the age range of 21-40 years which implies that they are still within the active and productive age while 23.40% and 18.30% of the respondents were between, 41-50 years and above 51years respectively. According to Omoregbee and Ajayi (2009) skills acquired through re-training and training programmes by young extension agents can be utilized in the organization for a long period of time. Majority (81.67%) of the extension agents were male and 18.33% were female. The result shows that extension work is dominated by male. However, the presence of female extension agent has changed the orientation that extension job was reserved for only men (Airemen, 2005). Majority (79.20%) of the respondents were married and 20.8% are single. Majority (54.20%)

of the extension agents had Bachelors' degree with 27.50% and 8.30% of them having Higher National Diploma (HND) and Masters/Postgraduate Diploma degrees respectively. Average years of working experience among the extension agents was found to be 13.22 years (SD = 9.66) with majority having their years of experience ranging between 1 and 10. Average years of involvement in sawah technology among extension agents was 1.84 years (SD = 2.49).

Table 8. Distribution of the respondents by their personal characteristics (N=120)

Variables	Frequency	Percentage	Mean	SD
Age (years)				
21-30	30	25.0		
31-40	40	33.3	39.4	10.3
41-50	28	23.4		
Above 51	22	18.3		
Sex				
Male	98	81.7		
Female	22	18.3		
Marital status				
Married	95	79.2		
Single	25	20.8		
Educational Level				
HND	45	27.5		
BSC	65	54.2		
PGD/MSC	10	8.3		
Years of working Experience				
1-10	59	49.2		
11-20	28	23.3	13.2	9.7
21-30	28	23.3		
Above 31	5	4.2		
Years of Involvement in Sawah				
1-3	53	44.2		
4-6	38	31.7	1.8	2.5
7-9	17	14.2		
Above 10	12	10.0		
Attendance in Previous Training				
Yes	22	18.3		

No	98	81.7
Number of Training Attended		
None	98	81.7
1-3	14	11.7
4-5	8	6.7

Source: Field Survey, 2010

Sources of information about sawah technology: Table 9 shows the sources of information among the respondents. The main sources of information on sawah technology highlighted by the respondents were research institutes/universities (89.20%), colleagues (80.00%), journals (69.20%) and the internet platforms. (66.70%).

Table 9: Respondents' sources of information about sawah technology (N=120)

Sources	*Frequency	Percentage
Research institutes/Universities	107	89.2
Colleagues	96	80.0
Journals	83	69.2
Internet	80	66.7
Newspaper	37	30.8
Local T.V	34	28.3
Radio	28	23.3

Magazines	10	8.3

Source: Field Survey, 2010; *Multiple responses provided

Training needs of the respondents on sawah technology: The training in the area of sawah layout and design was considered as the greatest need of the extension agents as revealed in Table 10. Ninety four percent of the extension agents indicated sawah layout and design as the area of priority in sawah development. This was followed by site selection for sawah rice production where 91.70% of the extension agents showed desire for training. About ninety percent of the extension agents indicated power tiller operation and management as the area they need training. Due to the importance of ploughing and puddling, eighty six percent of the extension agents indicated interest to be trained on ploughing and puddling of sawah field. Other areas of training needs include fertilizer usage (82.50%), irrigation and water management (81.70%), levelling (79.20%), smoothening (78.30%), weed control (75.00%), disease and pest control (70.80%) and nursery management (68.30%). These findings indicated that the areas in which respondents expressed training needs are very relevant to knowledge and skills required for the dissemination of sawah technology as well as responding to farmers' needs and challenges in the use of sawah technology. According to Androulitakis and Siardos (2005), extension agents' competence should be in accordance with the task areas in which they will be assigned to operate in order to perform successfully. Adhikarya (1996) and Pasteur (2002) also posited that extension training is more useful to staff when it is based on the needs of staff which can be determined by the staff themselves. Extension agents are vital to technology adoption because they provide the necessary links with farmers, communities and source of technology (scientists), manage on-farm research efforts, and deliver education and training programs (Erbaugh *et al.*, 2007). Assessing training needs of extension agents is an important element and a critical factor in the success of the sawah technology in Nigeria.

Table 10: Distribution of respondents by their training on sawah technology (N=120)

Training Areas	*Frequency	Percentage
Sawah layout and design	113	94.2
Site Selection for sawah rice production	110	91.7
Power tiller operation and management	107	89.2
Ploughing and puddling	103	85.8
Fertilizer usage	99	82.5
Irrigation and water Management	98	81.7
Levelling	95	79.2
Smoothening	94	78.3
Weed control	90	75.0
Disease and pest control	85	70.8
Nursery management	82	68.3
Purchase of farm inputs for sawah development	54	45.0
Transplanting	54	45.0
Harvesting	48	40.0
Processing	44	36.7

Source: Field Survey, 2010; *Multiple responses

Professional competencies required by extension agents: The result of the study shows that extension agents required professional training in the areas such as conducting demonstration (62.50%), communication skills (60.80%), farmers training (60.00%) and formation of farmers groups (48.30%). As reported by Gibson and Hillison (1994), (cited by Namdar *et al.*, 2010) competencies required by extension staff include communication, effective thinking, organizational management, programme planning, research and development, technical knowledge, human and social development. Singh and Mohammed (1982) reported that the main areas of competence required by extension agents were extension methods, communication, programme planning, and technical knowledge. Tladi (2004) found that the agents needed training in interpersonal communication skills, practical farm skills, conducting needs assessment surveys and mobilizing people to form groups. Programme planning, implementation and evaluation, public relations, personal and professional development, personal skills, management responsibility and work habits are the major areas of competency needed by an extension agent according to Namdar *et al.* (2010).

Table 11: Distribution of Professional competencies required by the extension agents (N=120)

Professional competencies	Frequency	Percentage	Rank
Conducting demonstration	75	62.5	1
Communication Skill	73	60.8	2
Farmers training	72	60.0	3
Formation of farmers groups	58	48.3	4
Farmer identification	25	20.8	5
Selection of contact farmers	14	11.7	6

Source: Field Survey, 2010;

Preferred training methods by the extension agents: The result of the study showed that seven training methods were selected by the extension agents as shown in Table 12. The preferred training methods by the extension agents are on-the-job training (70.00%), demonstration (55.80%), training of trainers (51.70%), field visitation and observation (46.70%) and workshop (44.20%). This finding is corroborated by Cho and Boland (2004) who reported that, on-the-job training serves to broaden and improve the technical skill of extension staff thereby increasing farmers' productivity. Also, good morale and incentives will be essential in organizing and conducting an on-the-job training as its success is determined by how it is planned. According to Fabusoro *et al.* (2007), demonstration as a training method involves practical teaching of improved practices. Demonstration plots show a step-by-step procedure on how a new practice is different from or can be compared with commonly used local practice. In addition, regular visit to model sawah sites around their coverage areas can improve extension agents' knowledge of sawah. During visits, questions on the grey areas can be asked from the sawah leaders and scientists thereby improving their knowledge.

Table 12: Preferred training methods used by the extension agents (N=120)

Training methods	Percentage	Frequency
On-the-job training	84	70.0
Demonstration	67	55.8
Field visitation and observation	56	46.7
Workshop	53	44.2
Group discussion	23	19.2
Lecture	9	7.5

Source: Field survey, 2010

Regression analysis showing the relationship between training needs and other variables: The result of regression analysis showed that training needs of extension agents was significantly related to years of involvement in Sawah ($\beta = 0.29$; $p<0.01$). This implies that training need of extension agents is influenced by their years of involvement in sawah technology. Also, there was a significant relationship between training need of extension agents and number of sawah training attended ($\beta = 0.28$; $p<0.01$). This also implies that training need of extension agents is influenced by the number of sawah training attended. Training need of extension agents was also significant related to attendance in previous sawah training by the extension agents ($\beta = 0.42$; $p<0.01$). The results of this study agree with Adesoji *et al.* (2006) who reported that the type of training attended before may expose an individual to more training needs. According to Adesoji *et al.* (2006) if training attended meets the immediate needs of an individual, that individual would want more training so as to meet the future needs. Age of respondents was not significantly related to the training needs of respondents. It is possible that age may not be a significant factor in determining training needs. Whether old or young, people can be trained and re-trained to enhance their competence on the job. Also sex of respondents was not significantly related to the training needs of respondents. Years of working experience had no significant relation with the respondents' training needs. Although it is expected that years of experience will influence the training needs of extension agents as reported by Omoregbee and Ajayi, (2009). This result may be as a result of the fact that sawah technology is relatively new in Nigeria. Most of the extension agents have not been involved in sawah technology as reported above. Hence, this may explain the reason for this result. As shown above, the average years of involvement in sawah technology among the extension agents is 1.84 years. It is expected that with adequate training, extension agent will be exposed to the rudiments of sawah technology.

Table 13. Regression analysis showing the relationship between some variables (N=120)

Variables	**SE**	**Std coefficient (*β*)**	**sig**
Constant	1.76		0.00
Age	0.03	0.14	0.14
Sex	0.46	0.08	0.30
Marital Status	0.46	0.01	0.91
Working Experience	0.46	0.02	0.83
Years of involvement in Sawah	0.55	0.29*	0.00
Sources of information	0.56	0.11	0.18
Number of sawah training attended	0.12	0.28*	0.00
Attendance in previous sawah training	0.47	0.42*	0.00
R	0.66		
R^2	0.44		
Df	111/119		
Adjusted R	0.40		
F- value	10.73		

Source: Field survey, 2010.

6.2.4. Conclusion and Recommendations

Emanating from this study is the need for training of extension agents in the technical areas of sawah technology such as sawah layout and design, site selection for sawah rice production, power tiller operation and management. Attention should also be given to improvement of the professional competencies of extension agents in the areas such as conducting demonstrations, farmers training and communication skill. The study therefore recommended that on-the-job training programme should be organised for the extension agents in areas highlighted by the extension agents. Also, regular in-service training should be organised for extension agents to improve their skills in disseminating sawah technology to the farmers. In addition, when organising trainings on sawah technology for extension agents, it is recommended that the years of involvement in sawah, attendance in previous sawah training and number of sawah training attended should be taking into account as these influenced their training needs. Sawah training preference should be given to extension agents who have never been involved in sawah technology and have never attended any training on sawah technology.

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CHAPTER 7

Physico-chemical and geochemical properties of sawah soils of inland valleys in Nigeria

7.1. Introduction

Rice is widely grown in Nigeria under the upland rain fed, inland shallow swamps, deep water and lowland irrigated production systems (Olayemi 1997; Oladele and Wakatsuki 2010). However production under these systems has not been able to meet the demand for rice in Nigeria. An average Nigerian consumes 24.8 kg of rice per year, representing 9 per cent of annual calorie intake (IRRI 2001). Nigeria has experienced rapid growth in per capita rice consumption during the last three decades, from 5 kg in the 1960s to 25 kg in the late 1990s (WARDA 2003). In 1990, Nigeria imported 224,000 metric tons of rice valued at US 60 million dollars. This increased to 345,000 metric tons in 1996 with a value of US130 million dollars. By 2001, rice import increased to 1.51 million metric tons valued at US288.1 million dollars (FAO 1994). In 2004, the total domestic rice demand is estimated at about 5 million tons while the annual domestic output of rice still hovers around 3.0 million tons, leaving the huge gap of about 2 million tons annually (NAMIS 2004). In 2010, Nigeria imported 2.0 million tons of rice mainly from Thailand and 73,000 tons of US parboiled rice, the highest level in several years (GAIN 2011). Self-sufficiency in rice production is now an important political-economic goal of the Nigerian government as a means through which farmers can enhance their efficiency and productivity (Bello 2004).

To improve rice production, attention must be shifted to the Inland Valleys (IVs) available across Nigeria, with high potential for lowland rice production. The values of IVs in crop production have been emphasised, especially for rice and rice-based cropping systems in West Africa (Annan-Afful *et al*. 2004). The IVs offer considerable potential for agricultural intensification and diversification due to their natural fertility and water availability. Efficient management and sustainable utilization of these inland valleys could therefore result in an increase in rice production and reduction in importation. Study has shown that only 15% or less of the total inland valleys in Nigeria has to date been under cultivation despite the agricultural potential of the inland valleys (IITA 1990; WARDA 1997; Abe *et al*. 2007) due to lack of understanding of inland valley ecosystems. Wakatsuki and Masunaga (2005) also reported that the inability to develop the lowland valleys for agriculture in West Africa accounted for the failure in achieving Green Revolution (GR). To this end, sawah technology for rice production was introduced to these inland valleys in Nigeria. Sawah refers to a levelled and bounded rice field with inlet and outlet for irrigation and drainage (Wakatsuki *et al.* 1998). According to Wakatsuki and Masunaga (2005), sawah is a multifunctional constructed wetland which is a prerequisite for realization of the objectives of GR as well as maintaining a sustainable ecological environment. The geological fertilization process and nitrogen fixation inherent in sawah based rice production system compensate for nutrients losses.

In Nigeria, 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 1986 (Hirose and Wakatsuki 2002). On-farm adaptive research and participatory trials on Sawah system research were conducted on the research sites for four years (1986–1990) by Japanese researchers. In partnership with Watershed Initiative in Nigeria, a Non Governmental Organization (NGO), Agricultural Development Project (ADP), Ministry of Agriculture, Niger state and National Cereals Research Institute (NCRI), the dissemination of the sawah technology took off in 2001 from villages previously identified in a diagnostic survey (Oladele and Wakatsuki 2010). Since then, the dissemination and adoption have continued in other parts of Nigeria.

Sawah-based system of rice production was reported to have contributed to the achievement of GR in Asia. The speed and scale with which it solved the food problem was remarkable and unprecedented, and it contributed to a substantial reduction in poverty and the launching of broader economic growth in Asia. With GR, per capita production of rice has increased from 200kg to more than 250kg in the last 40 years in Asia. With proper soil management of the IVs, the yield of rice in Nigeria could improve to level that can favourably compete with Asia thereby meeting the increasing demand for rice and contribute to food security in Nigeria.

As part of effort to effectively utilize sawah technology in improving rice production level and to alleviate persistence shortage in rice supply, there is need to understand the physico-chemical and geochemical properties of the sawah soils for the development and management of the inland valley ecosystems in Nigeria. Sustainable management of sawah in Nigeria will require a thorough evaluation of the soil fertility that is determined by physico-chemical and geochemical properties of the soils. Despite the importance of the physico-chemical and geochemical properties of the sawah soils in Nigeria, little information is available. Although Issaka *et al.* (1996), Buri *et al.* (2000) and Abe *et al*. (2007) conducted some basic soil surveys in inland valleys of West Africa, detailed study on the physico-chemical and geochemical properties of the sawah soils in Nigeria is required. This study therefore aims at investigating the physico-chemical and geochemical status of the sawah soils in Nigeria. This will provide basic information for sustainable management of sawah soils in Nigeria in order to meet up with the desired increase in rice production and to address the rice demand and consumption among Nigerians. The study will also develop recommendations for soil management for sustainable sawah rice production in Nigeria.

7.2. Materials and Methods

Study area and soil sampling

This study was carried out in five states in Nigeria where sawah rice production is being practiced. The states are Niger, Kaduna, Kwara, Ebonyin and Ondo. Data used in this study were collected in all the sawah sites in these states namely: Bida, Zaria, Ilorin, Abakaliki, and Akure. The sites are Ejeti, Emir, Etusegi, Nasarafu, Shabamaliki, Sheshibikun, Etundandan, Zaria, Ilorin, Abakaliki (Ishiagu) and Akure as shown in Fig. 1. Soils of the Bida area are of

Mesozoic (Cretaceous) origin, and are generally known as Nupe sandstone. The soils of Zaria are derived from Basement Complex rocks which are essentially granites, gneisses, migmatites, schists and qual1zites that are rich in quartz and low in divalent cations (Wall 1978). The soil of Ilorin is formed from the Precambrian basement complex rocks and it is under the grassland savannah forest cover and belong to the soil group called ferruginous soil. The soils of Abakaliki are derived from Cretaceous black shale and siltstone or shale and limestone (Abe *et al*. 2007). The soil of Akure is made up of ferruginous tropical soils. Crystalline acid rocks constitute the main parent material of these soils. The main features include a sandy surface horizon underlain by a weakly developed clayey, mottled and occasionally concretionary sub-soil. The soil is however sensitive to erosion and occasional water logging as a result of the clay sub-soil. The soils have an exceptional clayey texture, but combine good drainage and aeration with good properties of moisture and nutrient retention. The climatic information of the study area is shown in Table 1. Soil samples were collected at depth of 0-15cm, 15-30cm, 30-45cm and 45-60cm using auger sampler from all the sites.

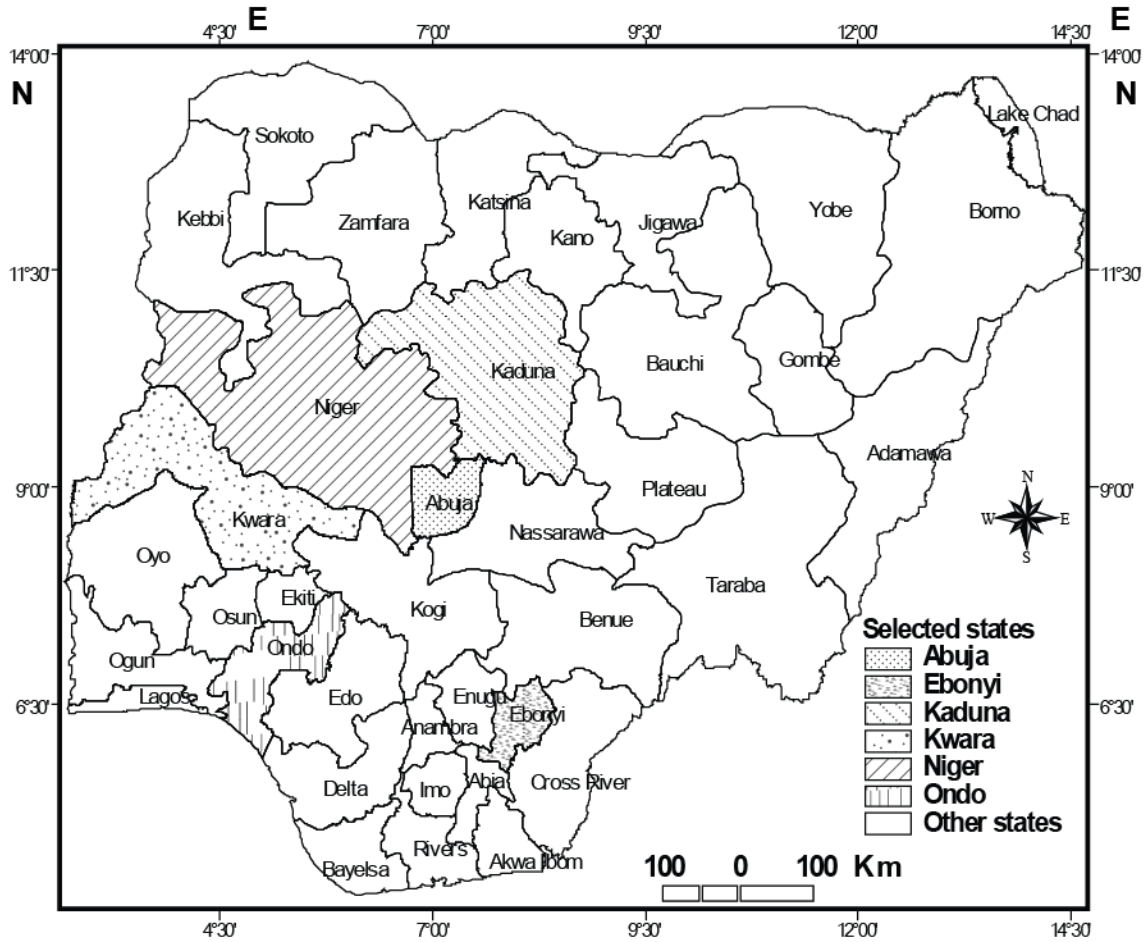

Fig 1: Map of Nigeria showing the study locations

Table 1: Sampling locations

Site	State	Relative humidity	Temperature	Annual Rainfall	Altitude
EJT 1	Niger	45% - 87%	23^o C-34^oC.	1100 mm-1200	97m
EJT 2	Niger				92m
EMR 1	Niger				76m
EMR 2	Niger				82m
ETS 1	Niger				77m
ETS 2	Niger				73m
NSF	Niger				71m
SHB	Niger				91m
SHE 1	Niger				71m
SHE 2	Niger				76m
ETD	Niger				126m
ZNK 1	Kaduna	20%-85%	10^oC- 42^oC	1000 mm -1200mm	598m
ZNK 2	Kaduna				593m
ILA 1	Kwara	75% - 80%	34^oC- 53^oC	1130mm-1800mm	384m
ILA 2	Kwara				381m
ILA 3	Kwara				376m
ISH 1	Ebonyi	60 – 80%	20°C- 38°C	1500 -2000 mm	54m
ISH 2	Ebonyi				47m
AKR 1	Ondo	80%	28^oC - 31^oC	1405 mm - 2400 mm	367m
AKR 2	Ondo				345m

Laboratory analyses

Soil samples were air-dried, ground and pass through a 2mm mesh sieve. Soil pH (H_2O and KCl) was measured with a pH meter (with a glass electrode) according to the method recommended by IITA (1979) and Mclean (1982) with a ratio of 1:2.5. Electrical Conductivity (EC) was determined using EC meter with glass electrode with a ratio of 1:5. Exchangeable cations were first extracted with 1*M* ammonium acetate solution pH7. Exchangeable Ca (ex. Ca) and exchangeable Mg (ex. Mg) were determined using Inductive Coupled Plasma Atomic Emission Spectroscopy (Shimadzu ICPE 9000, Kyoto, Japan). Exchangeable K (ex. K) and exchangeable Na (ex. Na) were determined using atomic absorption spectrophotometer (AA-680; Shimadzu, Kyoto, Japan). Available phosphorus (avail. P) content was determined by Bray 2 method (Bray and Kurtz 1945). Available Sulfur (avail. S) was first extracted with Di-potassium Hydrogen Phosphate (KH_2PO_4) and Inductively Coupled Plasma Atomic Emission Spectroscopy (Shimadzu ICPE 9000, Kyoto, Japan) was used to determine the avail. S. Available Silica (avail. SiO_2) was determined by colorimetric molybdenum blue method by extracting with acetate buffer with ascorbic acid (Imaizumi and Yoshida 1958). Air dried soil was extracted with 1*M* acetate buffer at pH 4.0 at a ratio of 1:10 for 5 hours at 40^{o}C with occasional shaking. After filtration with dry filter paper no 6, the concentration of Si was determined using the colorimetric molybdenum blue method. Total Carbon (TC) and Total Nitrogen (TN) were determined by the dry combustion method using N-C analyzer (MT-700 J-Science Co.Ltd., Kyoto, Japan) based on the same principle described by Nelson and Sommers (1982). For particle size distribution, sieving was employed to determine coarse sand (2.0-0.2 mm) and fine sand (0.2-0.02 mm), and the pipette method was used for silt (0.02-0.002 mm) and clay (<0.002 mm). Total elements were analysed using X-ray Fluorescence Spectrometry (XRF). The dried soil samples were ground for 20 minutes in an automatic agate mortar and pestle. Total SiO_2, TiO_2, Al_2O_3, Fe_2O_3 (total iron expressed as $Fe_2O_{3)}$, MnO, Na_2O, MgO, K_2O, CaO, and P_2O_5 abundance in the samples were determined by X-ray fluorescence (XRF) in the Department of Geoscience, Shimane University, using a RIX-2000 spectrometer (Rigaku Denki Co. Ltd.) equipped with Rh-anode X-ray tube. All samples were made on pressed powder disks, following Ogasawara (1987). Powdered soil samples were ignited at 10500C prior to major element analyses. Loss on Ignition (LOI) of samples was determined before preparing glass beads. A 1.8 g sample of soil was mixed with 3.6 g flux powder (a mixture of Li2B4O7: LiBo2 at ratio of 4:1), placed in a platinum crucible and put in a bead sampler machine (NT-2000, Tokyo Kagaku, Co) for making glass beads. The glass beads of soil samples were then placed in an XRF spectrometer (RIX-2000 spectrometer, Rigaku Denki Co. Ltd.) to determine major elements content. Ten elements (Si, Fe, Al, Ti, Mn, Mg, Ca, Na, K, and P) were analysed.

Weathering degree

The degree of weathering was determined by calculating the Chemical Index Alteration (CIA) (Nesbitt and Young 1982). The CIA reflects the proportion of primary and secondary minerals measured in soil samples and provides accurate measure of the degree of chemical weathering (Nesbitt and Young 1982). This was calculated using the formula below:

$$CIA = Al_2O_3 / (Al_2O_3 + CaO + Na_2O + K_2O) \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The mineral alteration is regarded as low when CIA is in range of 50 to 60, intermediate when it is between 60 and 80 and extreme for CIA greater than 80 (Fedo *et al*. 1995).

Statistical analysis

Statistical analysis was performed to determine the relationships between the soil fertility characteristics. Correlation analysis was used to determine the relationship that existed among soil fertility properties using the Statistical Package for Social Science (SPSS).

7.3. Results

Topsoil physico-chemical and geochemical properties

Physical properties

The result of the study showed that sawah topsoils in Nigeria are predominantly sandy (Table 2) with average value of 60.60%. Majority of the sites have values above 50% except in ETS 2, AKR 2, EMR 1 and EJT 1 with 35%, 45%, 48% and 24% sand respectively. The soils were low in both clay and silt with average values of 19.22% and 20.18% respectively. Sand content across all the sampling sites ranged between 24.31% and 81.99%, silt content ranged between 9.18% and 52.94% while clay content ranged between 5.38% and 36.36%. As shown in Table 2, sawah topsoils in Nigeria are categorised as sand clay loam found in AKR 1, EMR 1, EMR 2 and ILA 3; sandy clay found in AKR 2, silt loam found in EJT 1, loamy sand found in EJT 2 and ZNK 2; clay loam found ETS 2 and sandy loam found in ETS 1, ILA 1, ILA 2, NSF, SHB 1, ZNK 1, ISH 1, ISH 2, SHE 1, SHE 2 and ETD. In most cases, sand is higher than clay and silt added together.

Chemical characteristics

Generally, the sawah soils in Nigeria showed low topsoil pH values. Topsoil pH ranged between 4.6 and 6.8 with a mean topsoil value of 5.2 for pH H_2O. Topsoil pH KCl ranged between 3.7 and 5.8 with a mean topsoil value of 4.2. Both pH H_2O and pH KCl follow the same trend across the sampled soils. The pH was found to be moderately acidic to slightly acidic in the study area with few exceptions in Akure sites that showed slightly alkaline pH. Topsoil Electrical Conductivity (EC) values ranged between 0.007 dSm^{-1} and 0.066 dSm^{-1} with average of 0.016 dSm^{-1}. Although the values are low, the EC of sawah soils falls within the recommended limit of 0 - 4.0 $dSm^{-1}$for crop production. As shown in Table 3, topsoil ex. Ca ranged between 0.57 cmolc kg^{-1} and 21.22 cmolc kg^{-1} with topsoil average of 3.51 cmolc kg^{-1}. The values of ex. Ca were generally low across all the sampling locations in Nigeria. Highest value of ex. Ca was observed in Akure sites. Ex. K content of the sawah topsoil was low with mean content of 0.32 cmolc kg^{-1}. Ex. K showed a range of between 0.12 cmolc kg^{-1} and 0.60 cmolc kg^{-1} with topsoil average of 0.32 cmolc kg^{-1}. Sawah soil in Nigeria are characterised by low Ex. K with highest values observed in Akure. Observed Ex. Mg in sawah soils was low. The topsoil ex. Mg ranged between 0.11 cmolc kg^{-1} and 5.63 cmolc kg^{-1} with topsoil average of 0.99 cmolc kg^{-1}. Topsoil ex. Na ranged between 0.09 cmolc kg^{-1} and

1.49 cmolc kg^{-1} and with topsoil average of 0.37 cmolc kg^{-1}. Ex. Na was generally low in sawah soils in Nigeria. Topsoil avail. P in the sawah soils in Nigeria was low ranging from 4.36 mg kg^{-1} to 323.35 mg kg^{-1} with topsoil average of 41.12 mg kg^{-1}. There was considerably high avail. P in AKR 1 and 2. AKR 1 and 2 are located in the Southwest part of Nigeria. This high value agreed with Issaka *et al*. (1996) that reported that soils in Southwest Nigeria had high avail. P compared to other inland valleys in West Africa. Topsoil avail. SiO_2 values ranged between 24.65 mg kg^{-1} and 688.46 mg kg^{-1} with topsoil average of 130.71 mg kg^{-1}. There was considerably high avail. SiO_2 in Akure which considerably affected the average value. Observed avail. S level was generally low in sawah soils across all the sampling locations compared to the critical level of 8 mg kg^{-1}as recommended Yamaguchi (1997). Topsoil avail. S values ranged between 3.56 mg $kg^{-1}$and 31.25 mg $kg^{-1}$with topsoil mean value of 9.57 mg kg^{-1}. Although the average value is higher than the critical level, however majority of the sites have values below the critical level. Highest value of avail. S was observed in Akure sites which considerably affected the average value. The content of TN was generally low in sawah soils in Nigeria. The content of Topsoil TN ranged between 0.24 gkg^{-1} and 3.01 gkg^{-1} with topsoil average value of 0.80 gkg^{-1}. Following a similar trend, topsoil TC in sawah soils in Nigeria can be categorised as low. The content of TC ranged between 2.94 gkg^{-1} and 29.10 gkg^{-1} with topsoil average value of 8.97 gkg^{-1}.

Geochemical properties and weathering degree

The result of the study as shown in Table 3 revealed that topsoil total elemental SiO_2 ranged between 67.57% and 94.47% in sawah soils in Nigeria. The average topsoil SiO_2 is 85.96%. Majority of the locations sampled had values above the average. TiO_2 ranged between 0.60% and 6.39% with an average of 1.77%. Majority of the locations sampled had values above the average TiO_2 value. Al_2O_3 values ranged between 2.60 % and 13.63% with a mean of

7.61%. Fe_2O_3 ranged between 0.49% and 9.18% with an average of 2.59%. The average value of MnO is 0.06% and ranged between 0.02% and 0.27%. MgO ranged between 0.06% and 0.70% with an average of 0.18%. CaO values ranged between 0.08% and 1.83% with a mean of 0.33%. Na_2O ranged between 0.17% and 1.24% with an average of 0.42%. The result of the study further showed that K_2O ranged between 0.29% and 3.96% in sawah soils in Nigeria with average of 1.05%. P_2O_5 values on the other hand ranged between 0.01% and 0.23% with a mean of 0.04%. The result also showed that SiO_2, Al_2O_3 and Fe_2O_3 dominated, accounting for a cumulative average of 96.16%. Except TiO_2 and K_2O which showed average values of >1%, MnO, MgO, CaO, Na_2O and P_2O_5 showed average values of < 1%. The result of the study further revealed that sawah soils in Nigeria have CIA values ranging from 67.45 and 91.50. Based on the interpretation of CIA value as prescribed by Fedo *et al*. (1995), sawah soils in Nigeria exhibited intermediated (CIA 60 - 80) to extreme weathering rate (CIA>80). Majority of the soil sampled fall into the category of extreme weathering rate. With extreme degree of weathering, rapid loss of mobile species such as base cations (Ca, Mg, K and Na) from soil is eminent which may account for the results observed in this study.

Correlation analysis between soil fertility parameters

Correlation analysis shown in Table 4 revealed that there is a significant relationship between TC and avail. S and avail. P. TC was also found to be significantly related to total elemental P_2O_5. The results also showed similar significant relationship between TN and avail. S and avail. P. TN was also found to be significantly related to total elemental P_2O_5. Clay content showed a significant relationship with total elemental P_2O_5. Sand content showed a negative correlation TC, TN and total elemental P_2O_5. The result also revealed that CIA is correlated with avail. P. avail. SiO_2, clay content, total elemental CaO, Na_2O, K_2O, TiO_2, Fe_2O_3 and P_2O_5.

Profile distribution of soil fertility parameters

Particle size analysis revealed that clay content of sawah soils increased with increase in depth from topsoil down to subsoil except in few cases with erratic distribution. Silt content of sawah soils in Nigeria showed a decreasing trend in depth from topsoil down to subsoil. Silt content however showed some variations in some sampling points without clear-cut trends. Sand showed erratic trend in most of all the sampling point with variations in depth from topsoil down to subsoil. pH increased with increase in depth from topsoil down to subsoil. The profile distribution revealed that the pH level increased with depth with few exceptions where the pH level decreased with depth. AKR 1, EMR 2, ETU 2, ILA 1, SHB, ZNK 2, ISH 1, ISH 2 and SHE 1 showed the same trend with an increase in the pH from topsoil down to subsoil. The EC values generally followed the opposite trend as pH with decrease in the value of EC with the depth from topsoil down to subsoil with only few exceptions . With exception in few cases, ex. Ca decreased with increase with the depth from topsoil down to subsoil. Ex. K decreased with increase with the depth from topsoil down to subsoil . Ex. Mg increased slightly in some locations and also decreased with depth from topsoil down to subsoil in other locations. Ex. Na increased with the depth from topsoil down to subsoil which may be due to leaching of the topsoil and accumulation in the subsoil. Avail. P decreased with increase the depth from topsoil down to subsoil. Avail. SiO_2 values increased with the depth from topsoil down to subsoil except in few occasions. Avail. S level was comparatively higher in the topsoil across all the sampling locations. Avail. S decreased with increase in depth from topsoil down to subsoil with some exceptions where there was erratic distribution within the soil profile. TN values were comparatively higher in the topsoil across all the sampling locations and decreased with increase in depth of the profile. As observed in TN, TC values were comparatively higher in the topsoil across all the sampling locations and decreased with increase in depth from topsoil down to subsoil.

7.4. Discussion

The physical characteristics of soil particularly texture significantly influence the other characteristics of soils. Particle size distribution is critical in relation to soil behaviour and management. The properties of individual particles and their distribution in the soils are subjected to limited human control. According to Lund et al. (1999), the diverse ratios of sand, silt, and clay in the soil results in soil variations which has a direct effect on yield. These variances affect the water-holding capacity, nutrient leaching, and plant root stability in soils. Soil physical properties also play a significant role in the chemical properties of soil. Sawah soils in Nigeria are generally sandy (Table 3) having values above 50%. As reported by previous authors (Buri *et al*. 2000 and Issaka *et al.* 1996) inland valleys in West Africa are dominated by low clay content having been derived from granites and Pre-Cambrian metamorphic rocks, generally referred to as Basement Complex. The result revealed a

Table 2: TopSoil Physico-chemical properties of sawah soils in Nigeria

		pH			Exchangeable cations (cmol$_c$ kg^{-1})															
S/N	Sites	H_2O	KCL	EC (d Sm^{-1})	Ca	K	Mg	Na	Bray-2 P (mgkg^{-1})	Avail SiO_2 (mgkg^{-1})	Avail S (mgkg^{-1})	TN gkg^{-}	TC gkg^{-1}	C/N	Clay (%)	Silt (%)	C.Sand (%)	F.Sand (%)	Sand (%)	Textural Class
1	AKR 1	5.13	4.34	0.052	7.11	0.40	2.74	0.75	90.21	135.60	28.67	1.36	15.04	11.06	23.89	12.88	35.95	27.28	63.23	Sand clay loam
2	AKR 2	6.43	5.75	0.130	21.22	0.48	5.63	1.49	323.35	688.46	31.25	3.01	29.10	9.67	34.64	20.31	12.24	32.81	45.05	Sandy clay
3	EJT 1	4.93	4.28	0.048	3.56	0.49	0.77	0.22	49.21	106.39	10.88	1.49	17.86	11.99	22.75	52.94	1.31	23.00	24.31	Silt loam
4	EJT 2	5.42	4.76	0.020	1.72	0.12	0.37	0.37	21.87	81.11	5.07	0.36	4.70	13.06	5.38	14.75	26.14	53.73	79.86	Loamy sand
5	EMR 1	4.85	3.95	0.022	1.77	0.48	0.54	0.40	8.30	107.57	7.18	0.45	5.47	12.08	22.79	29.45	4.17	43.58	47.75	Sandy clay loam
6	EMR 2	4.75	3.74	0.018	2.09	0.36	0.63	0.42	12.96	145.10	6.84	0.43	4.38	10.18	25.60	13.95	15.88	44.58	60.46	Sandy clay loam
7	ETS 1	4.98	4.23	0.021	2.29	0.31	0.41	0.29	12.77	89.43	6.95	0.56	6.55	11.67	14.99	27.30	5.72	52.00	57.72	Sandy loam
8	ETS 2	4.86	3.92	0.016	2.75	0.36	0.54	0.26	10.79	130.11	7.78	0.57	6.25	10.96	36.36	28.36	1.11	34.17	35.28	Clay loam
9	ILA 1	4.64	3.79	0.031	3.54	0.37	1.12	0.49	29.26	260.30	9.45	0.87	9.81	11.28	16.91	14.64	41.01	27.44	68.45	Sandy loam
10	ILA 2	4.79	4.02	0.010	2.74	0.58	0.79	0.41	4.36	174.44	5.85	0.29	3.05	10.52	20.97	24.43	25.54	29.06	54.60	Sandy loam
11	ILA 3	4.63	3.91	0.038	1.47	0.27	0.62	0.16	54.95	24.65	9.87	1.27	14.94	11.76	29.50	15.37	24.44	30.69	55.13	Sandy clay loam
12	NSF 1	6.11	4.55	0.016	2.34	0.13	1.19	0.28	6.95	28.25	3.56	0.24	3.85	16.04	13.07	10.95	38.13	37.85	75.97	Sandy loam
13	SHB 1	4.98	4.65	0.032	1.83	0.19	0.89	0.16	32.59	63.42	6.71	0.60	7.37	12.28	16.15	19.13	33.20	31.53	64.72	Sandy loam
14	ZNK 1	6.82	4.24	0.015	5.79	0.60	1.73	0.56	15.85	53.24	6.33	0.57	7.20	12.63	13.37	9.18	24.89	52.55	77.44	Sandy loam
15	ZNK 2	5.08	4.42	0.022	0.58	0.13	0.13	0.09	19.03	39.73	10.44	0.71	9.38	13.21	6.03	11.98	19.87	62.12	81.99	Loamy sand
16	ISH 1	4.76	4.12	0.026	1.37	0.50	0.35	0.27	34.54	55.01	8.39	0.94	10.37	11.03	18.95	13.21	12.17	55.67	67.84	Sandy loam
17	ISH 2	4.71	3.73	0.025	0.57	0.16	0.11	0.14	20.58	77.98	6.75	0.93	10.23	11.00	20.16	24.42	3.15	52.27	55.42	Sandy loam
18	SHE 1	5.25	4.03	0.013	2.32	0.15	0.43	0.22	5.46	54.62	5.15	0.33	3.66	11.09	7.51	19.40	23.08	50.02	73.09	Sandy loam
19	SHE 2	5.97	4.05	0.011	1.50	0.13	0.31	0.16	6.06	74.36	6.24	0.29	2.94	10.14	19.40	16.98	13.69	49.93	63.62	Sandy loam
20	ETD 1	4.75	3.96	0.027	3.58	0.21	0.54	0.29	63.25	224.34	8.06	0.64	7.22	11.28	15.96	23.95	3.24	56.85	60.09	Sandy loam

Table 3: Topsoil total elements of sawah soils in Nigeria

Site	SiO_2 (%)	TiO_2 (%)	Al_2O_3 (%)	Fe^2O_3 (%)	MnO (%)	MgO (%)	CaO (%)	Na_2O (%)	K_2O (%)	P_2O_5 (%)	LOI	CIA
AKR 1	73.77	6.39	8.96	8.03	0.10	0.45	1.09	0.58	0.56	0.07	4.49	80.07
AKR 2	67.57	5.04	13.61	9.18	0.27	0.70	1.83	0.62	0.93	0.23	9.26	80.09
EJT 1	85.77	2.29	8.87	1.48	0.03	0.13	0.19	0.21	0.99	0.05	5.56	86.45
EJT 2	94.26	1.25	2.60	1.05	0.04	0.07	0.12	0.18	0.42	0.01	1.63	78.40
EMR 1	86.98	1.49	7.72	1.74	0.04	0.12	0.25	0.33	1.31	0.02	3.19	80.39
EMR 2	87.07	1.02	7.85	2.58	0.03	0.12	0.21	0.26	0.84	0.02	3.47	85.66
ETS 1	89.49	1.48	6.40	0.96	0.04	0.11	0.15	0.21	1.14	0.02	3.14	81.13
ETS 2	80.24	1.73	13.63	2.07	0.04	0.17	0.20	0.26	1.63	0.03	5.13	86.71
ILA 1	88.36	1.54	6.10	3.13	0.05	0.13	0.17	0.22	0.29	0.04	4.02	90.03
ILA 2	84.49	2.18	7.87	4.21	0.07	0.19	0.20	0.23	0.51	0.04	3.28	89.26
ILA 3	88.65	1.62	6.91	1.85	0.04	0.14	0.20	0.24	0.32	0.03	4.66	90.09
NSF 1	94.47	0.97	2.89	0.49	0.02	0.06	0.09	0.19	0.81	0.01	1.24	72.58
SHB 1	91.32	1.25	5.34	0.90	0.02	0.08	0.08	0.18	0.82	0.02	2.51	83.10
ZNK 1	82.05	0.60	10.38	1.77	0.03	0.16	0.34	0.71	3.96	0.01	2.53	67.45
ZNK 2	85.51	0.66	8.37	1.37	0.03	0.14	0.42	0.73	2.76	0.01	2.64	68.18
ISH 1	88.25	0.72	6.58	2.34	0.03	0.21	0.22	1.22	0.40	0.04	2.84	78.24
ISH 2	84.38	0.89	9.11	3.15	0.02	0.28	0.22	1.24	0.67	0.04	3.35	81.00
SHE 1	90.37	1.10	4.96	1.56	0.18	0.08	0.26	0.31	1.17	0.01	1.59	74.08
SHE 2	88.18	1.17	7.32	1.41	0.03	0.11	0.29	0.31	1.18	0.01	2.52	80.53
ETD 1	88.03	1.92	6.74	2.50	0.04	0.11	0.10	0.17	0.36	0.04	3.38	91.50

CIA = Chemical Index Alteration; LOI = Loss of Ignition

Table 4: Correlation matrix between topsoil fertility parameters of sawah soils in Nigeria (N = 18)

	PH H2O	PH KCL	EC	Ca	K	Mg	Na	P2O5	SiO2	S	N	C	C/N	Clay %	Silt	Sand	SiO_2	TiO_2	Al_2O_3	Fe_2O_3*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
PH KCL	0.44																									
EC	-0.42	0.26																								
Ex. Ca	0.42	-0.03	-0.18																							
Ex. K	-0.04	-0.28	0.18	0.56																						
Ex. Mg	0.53	0.15	-0.15	0.81	0.47																					
Ex. Na	0.25	-0.15	-0.29	0.69	0.63	0.64																				
Av. P2O5	-0.38	-0.03	0.56	0.12	0.00	-0.01	-0.21																			
Av. SiO2	-0.43	-0.47	-0.12	0.38	0.28	0.12	0.49	0.19																		
Av. S	-0.51	-0.26	0.62	-0.02	0.24	-0.17	-0.24	0.63	0.20																	
TN	-0.42	-0.19	0.69	0.01	0.23	-0.05	-0.28	0.74	-0.01	0.82																
TC	-0.35	-0.09	0.73	0.02	0.20	-0.01	-0.29	0.74	-0.08	0.82	0.99															
C/N	0.47	0.70	0.24	0.05	-0.27	0.36	-0.03	-0.04	-0.44	-0.24	-0.11	0.01														
Clay	-0.40	-0.59	0.09	0.03	0.40	0.01	-0.01	0.14	0.21	0.30	0.33	0.26	-0.45													
Silt	-0.37	-0.12	0.50	0.12	0.28	-0.17	-0.16	0.23	0.23	0.35	0.44	0.43	-0.22	0.37												
Sand	0.46	0.39	-0.39	-0.09	-0.40	0.11	0.11	-0.23	-0.26	-0.40	-0.47	-0.42	0.38	-0.78	-0.87											
SiO_2	0.09	0.54	0.04	-0.29	-0.55	-0.05	-0.12	0.07	-0.21	-0.40	-0.25	-0.20	0.46	-0.53	-0.28	0.47										
TiO_2	-0.46	-0.18	0.21	0.25	0.28	0.02	0.06	0.34	0.55	0.27	0.25	0.23	-0.27	0.44	0.73	-0.73	-0.12									
Al_2O_3	-0.09	-0.50	0.01	0.24	0.47	0.01	0.02	-0.04	0.14	0.42	0.27	0.23	-0.44	0.63	0.33	-0.56	-0.97	0.14								
Fe_2O_3*	-0.47	-0.71	-0.18	0.10	0.46	-0.03	0.32	0.04	0.63	0.18	0.11	0.02	-0.63	0.35	0.06	-0.22	-0.52	0.29	0.37							
MnO	-0.07	-0.17	-0.39	0.04	-0.10	-0.14	0.00	-0.25	0.03	-0.25	-0.27	-0.30	-0.26	-0.25	0.03	0.12	0.12	0.11	-0.19	0.10						
MgO	-0.29	-0.53	0.08	-0.15	0.36	-0.22	-0.07	0.03	0.06	0.26	0.38	0.31	-0.42	0.39	0.12	-0.29	-0.68	-0.08	0.60	0.67	-0.23					
CaO	0.26	-0.20	-0.12	-0.06	0.17	-0.13	-0.08	-0.30	-0.30	0.30	0.04	0.06	-0.16	-0.11	-0.17	0.17	-0.55	-0.43	0.48	0.09	0.11	0.31				
Na_2O	0.00	-0.19	0.15	-0.29	0.10	-0.27	-0.19	-0.03	-0.32	0.13	0.26	0.23	-0.11	-0.08	-0.22	0.19	-0.34	-0.61	0.27	0.26	-0.20	0.76	0.47			
K_2O	0.63	0.17	-0.15	0.38	0.22	0.33	0.16	-0.33	-0.34	0.03	-0.14	-0.08	0.22	-0.20	-0.17	0.22	-0.50	-0.45	0.48	-0.25	-0.09	0.04	0.72	0.23		

P_2O_5	-0.59	-0.48	0.40	0.16	0.44	-0.09	-0.02	0.54	0.53	0.55	0.65	0.58	-0.46	0.47	0.59	-0.64	-0.46	0.60	0.41	0.67	-0.12	0.62	-0.17	0.20	-0.38	
CIA	-0.70	-0.48	0.11	0.05	0.17	-0.09	0.05	0.47	0.68	0.33	0.32	0.24	-0.53	0.63	0.42	-0.62	-0.10	0.79	0.13	0.51	-0.05	0.12	-0.53	-0.41	-0.70	0.66

Note: r = 0.468 significance <5%; r = 0.590, significance <1%

positive correlation although not significant between sand and total elemental SiO_2 (r = 0.47) which means high sand content in soil increases the SiO_2 content. The high content of sand fraction of sawah soils means that the soils water retention capacity is low and cannot be able to hold nutrients resulting into high level of leaching which have contributed to the general low fertility status of these soils. The low content of clay in these soils contributes to high leaching especially as observed in ex. Na which increases in values with increase in soil depth. The high content of clay in ETS 2 and silt in EJT 1 will be an advantage for these locations for sawah rice development. The clay content of soil play a major role in its nutrient supplying ability as well as it water holding capacity (Buri *et al*. 1999).

The pH was found to be moderately acidic to slightly acidic in the entire site but with few exceptions in Akure site that showed slightly alkaline pH. The acidic nature of parent rocks and intense leaching under high rainfall is responsible for the acidic reaction of the soils (Abe *et al*. 2007). Application nitrogen fertilizers commonly adopted by farmers in Nigeria account for the acidic condition which in turn worsening the fertility of the soils. Electrical conductivity (EC) values ranged between 0.005 dSm^{-1} and 0.26 $dSm^{-1}$with topsoil average of 0.02 dSm^{-1}. The EC values are generally low and followed opposite trend as pH, decreasing in the value as the depth increases with only few exceptions. Chabra *et al.* (1996) and Pereir *et al*. (1986) reported that soils exposed to high rainfall will have low soluble salts concentration because of leaching losses and in turn results in decreased electrical conductivity. The EC values are low in the study area but fall within the recommended limit for crop production. Corresponding with the low pH, the contents of exchangeable bases were very low. The values of ex. Ca were generally low across all the sampling locations in Nigeria. Ex. K content of the soils was low with mean content of 0.26 $cmol_c kg$-1. Ex. Na was generally low in sawah soils in Nigeria except in few occasions where ex. Na was moderate and increased slightly with depth of the soil profile. The low level of exchangeable bases is due to leaching of the topsoil and accumulation in the subsoil. In addition, flooding condition of the soils which reduced the pH at the surface of the sawah soils also account for the nature of the exchangeable cations found in sawah soils in Nigeria. Low exchangeable bases are also associated with the low level of clay across all the sample locations. The soils are low in clay and hence may be susceptible to leaching. Buri *et al.* (2000) also reported that low colloidal activity as a result of low organic matter and erratic rainfall distribution and low clay activity in West Africa provided an environment where cations retention and overall build-up soil plant nutrient is very low. The low content of exchangeable bases is also due to high degree of weathering as shown by high CIA values obtained in this study. As prescribed by Fedo *et al*. (1995) sawah soils in Nigeria exhibited intermediated (CIA 60-80) to extreme weathering rate (CIA>80). Majority of the soil sampled fall into the category of extreme weathering rate. With extreme degree of weathering, rapid loss of mobile species such as base cations (Ca, Mg, K and Na) from soil is eminent which account for the results observed in this study. The high level of SiO2, Al_2O_3 and Fe_2O_3 and low level of total base elements (K_2O, CaO, Na_2O and MgO) is also an indication of low fertility status obtained in this study. Low organic matter content of the study sites also points to the low level of exchangeable cations. Avail. P in the sawah soils in Nigeria is low. The result is supported by previous reports of Annan-Afful *et al.* (2004) and Abe *et al.* (2007) who reported an average avail. P of 4.9 $mgkg^{-1}$ in sawah soils in Ashanti region of Ghana and a range of between 1.0 $mgkg^{-1}$ and 9.0 $mgkg^{-1}$ in eastern Nigeria respectively.

As there has not been any study on availability of silica in lowland soils in Nigeria to the best of our knowledge, we compare the result to the critical level recommended by authors in tropical Asia and Japan. According to Sumida (1992), the critical value of avail. SiO_2 content for rice growth is 300 $mgkg^{-1}$ of SiO_2. Also, Bollich and Matichenkov (2002) described values less than 300 $mgkg^{-1}$ of SiO_2 as deficient and values less than 600$mgkg^{-1}$ of avail.

SiO_2 as low for rice and sugarcane. According to IRRI (2000), the critical value of avail. SiO_2 content for rice growth is 86 mgkg^{-1}. Based on Sumida (1992), sawah soils in Nigeria are deficient in avail. SiO_2 except in Akure 2 where the topsoil recorded a high level of silica, other sites ranged from low to deficient in available silica. Based on IRRI (2000), majority of the soils had values below the critical level of 86 mgkg^{-1}. Silicon is as beneficial element for rice plants and as one of the major factors affecting the sustainability of rice production (Husnain *et al*. 2008; Sumida, 2002), sawah soils in Nigeria need silicate amendment for optimum rice production. Silicon can control rice diseases such as blast, sheath blight in rice, and powdery mildew in cucumber (Ishizuka and Hayakawa 1951; Kawashima 1927; Miyake and Takahashi 1983; Ma *et al*. 2001). Silica according to Iler (1979) is able to displace phosphate ions from the soil surface. Ma *et al*. (2001) also reported that silicon is essential in alleviating water stress by decreasing transpiration and is beneficial to rice under P deficiency (as found in the present study locations) and excess of P, Na, Mn, N and Al.

Avail. S level was low in the topsoil across all the sampling locations showing values below the critical level of 8 mg kg^{-1}as recommended Yamaguchi (1997). According to Yamaguchi (1997), sulfur status is a key factor controlling rice productivity. The result of this study is in agreement with previous results of Osiname and Kang (1975), Enwezor (1976) Kang et al. (1981) and Buri et al. (2000) who reported similar low level of sulfur in West Africa. The result also showed that avail. S is significant correlated with TC and TN. According to Buri et al. (2000), poor organic matter management has a great effect on sulfur deficiency. In addition to organic matter, volcanic activity which supply sulfur to soil through precipitation is absent in the study area (Buri et al., 2000) and may also account for the low level of sulfur observed in this study. TC and TN were observed to be low across all the sawah soils in Nigeria. Organic matter according to Oyediran (1990) is effective in increasing and retaining most cations. Poor organic matter content resulting in low TC and TN plays a major role in low cation level found in this study. In addition, farming practices that encourage the burning of plant residue and annual burning of vegetation especially during the dry season (slash and burn) commonly found in the study areas also account for the low content of TC and TN. The values of TC and TN decreased with increase in depth down the soil profile. The comparably high TC and TN on the topsoil was as a result of large biomass production in the tropical condition found in the study locations.

Total elemental SiO_2, Al_2O_3 and Fe_2O_3 dominated total elements, accounting for a cumulative average of 96.16%. Total elemental SiO_2 was the most abundant element accounting for between 67.57% and 94.47% of total weight. There also existed a positive correlation between total elemental SiO_2 and sand. This implies a strong chemical weathering process of the soils and sand size particles are dominated by SiO_2. Al_2O_3 values ranged between 2.60 % and 13.63% with a mean of 7.61%. Fe_2O_3 ranged between 0.49% and 9.18% with an average of 2.59%. Both Al_2O_3 and Fe_2O_3 were positively correlated with clay contents ($r = 0.63$; $r = 0.35$ respectively) suggesting that Al_2O_3 occurs in the form of clay and alluminosilicate minerals, and consists of SiO_2 and Al_2O_3 produced through weathering of parent materials. The correlation also suggests that the clay fraction not only consists of alluminosilicate minerals but also free iron oxides, which is formed from iron released from parent materials during weathering processes. Total elemental MgO content was low and ranged between 0.06% and 0.70%. The low level of total elemental MgO may also be responsible for low level of Ex. Mg found in this study. P_2O_5 values ranged between 0.01% and 0.23% and positively correlated with clay content. The result was also supported by Yichu *et al*. (1984) who reported a similar relationship between phosphorus and clay. According to Lair *et al*. (2009), phosphorus retention and release was correlated with clay-sized particles. Clay-sized particles represent the soil fraction with the highest and most reactive surface area.

Base on the result of the study, Akure sites (AKR 1 and AKR 2) had peculiar characteristics among the locations. Akure sites are higher than other location in all the soil fertility parameters under investigation and hence affected the overall result. The result from Akure may be as a result of few reasons which include geological fertilization, fertilizer application, flooding and vegetation. Akure is located in the southwest of Nigeria with thick forest. According to Issaka et al. (1996), in the equatorial forest zone, base-rich sediments of Tertiary-Quaternary, relating to volcanic activities may account for the presence of soils rich in exchangeable cations, phosphorus, high pH and other fertility parameters found in Akure sites. We intend to carry out a further research to ascertain the reason(s) for this variation.

The general low level of soil fertility parameters found in the study areas is due to the high level of weathering. As reported in Table 2, the CIA values of the soils revealed that sawah soils in Nigeria fall within intermediated (CIA 60-80) to extreme weathering rate (CIA>80) which may result in high level of leaching. Extreme degree of weathering leads to rapid loss of mobile species such as base cations. The role of the climate cannot also be over emphasised. Climate seems to exert a great effect on the availability of organic matter which has a pronounced effect on the amount of TN, TC, avail. P, exchangeable cations and avail. S. High temperature and rainfall of the study area as shown in Table 1 could aid the rapid decomposition of organic matter. High precipitation couple with the sandy nature of soils could also lead to high rate of leaching of major nutrients especially exchangeable bases.

7.5. Conclusion

This study investigated the physico-chemical and geochemical compositions of the sawah soils in Nigeria. This study has provided useful information that may be useful in order to improve sawah rice production thereby increase rice production in Nigeria. The study revealed that sawah soils in Nigeria are predominantly sand. The study further revealed that sawah soils are acidic and lacking in basic fertility parameters such as exchangeable bases, TC, TN, avail. S avail. P and avail. SiO_2. The result also shows that total elemental SiO_2, Al_2O_3 and Fe_2O_3 dominated total elements in sawah soils in Nigeria. Sawah soils in Nigeria exhibited intermediated to extreme weathering rate with majority of the soil sampled falling into the category of extreme weathering rate. With extreme degree of weathering, rapid loss of mobile species such as base cations (Ca, Mg, K and Na) from soil is eminent resulting in low fertility status of sawah soils in Nigeria. Unfavourable farm management practices such as continuous cropping without proper nutrient replenishment also account for the soil depletion of some of the nutrients. Leaching of major nutrients due to high sand proportion in the soil, high rainfall and low level of organic matter also contributed to the low fertility level of the soils. Application nitrogen fertilizers commonly adopted by farmers in Nigeria account for the acidic condition which in turn worsening the fertility of the soils.

As soil physical characteristics especially texture are subjected to little human control, to ameliorate the trend of depletion in the fertility of sawah soils, combination of conservative agricultural practices which encourage organic matter accumulation and recycling is recommended. Organic matter amendment must also be encouraged based on the enormous role of organic matter in improving the availability of exchangeable bases status. Effective organic matter management is necessary and a key factor in improving the base cations of these soils. Poor farm management through removal of crop biomass (such as rice straw and weeds) by farmers used for feeding livestock and other purposes should be discouraged while encouraging recycling crop biomass with the soil to add organic matter to the soil. Adoption of leguminous crops in rotation with rice especially after harvest of rice is also recommended as this will increase nitrogen through bacteria fixation and reduce the use of nitrogen fertilizers thereby reduce the acidic condition of the soils. Further study of silica dynamics in sawah soils in Nigeria is recommended. Due to the importance of silica in rice production, a detail study will provide a recommended rate of silica which will improve rice production in Nigeria is needed. Also, a study to ascertain the dynamics of nutrient in lowland in Akure site is recommended.

7.6. References

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CHAPTER 8

Micronutrient availability in sawah soils of inland valleys in Nigeria

8.1. Introduction

Rice is important in the food economy of Nigeria and the sixth major crop cultivated in area after sorghum, millet, cowpea, cassava and yam (Ojehomon *et al*., 2006). Rice is now a structural component of the Nigerian diet and rice imports make an important share of Nigerian agricultural imports (Ogundele and Okoruwa, 2006). Apart from rice serving as an important component of Nigerian diet, the role rice played in employment generation cannot be overlooked. Rice production provides employment for more than 80% of the people in various activities along the production/distribution chain from cultivation to consumption (Ogundele and Okoruwa, 2006). The consumption of traditional cereals, mainly sorghum and millet, has fallen by 12kg per capita, and their share in cereals used as food dropped from 61% in the early 1970s to 49% in the early 1990s. In contrast, the share of rice in cereals consumed grew from 15% to 26% over the same period. (Akpokodje *et al*., 2002; Ogundele and Okoruwa, 2006). Average yield of upland and lowland rainfed rice in Nigeria is 1.8 ton per hectare, while that of the irrigation system is 3.0 ton/ha (PCU, 2002). This is very low when compared with 3.0 ton/ha from upland and lowland systems and 7.0 ton/ha from irrigation systems in places like Côte d'Ivoire and Senegal (WARDA and NISER, 2001; Ogundele and Okoruwa, 2006). An average Nigerian consumes 24.8 kg of rice per year, representing 9 per cent of annual calorie intake (IRRI 2001). Nigeria has experienced rapid growth in per capita rice consumption during the last three decades, from 5 kg in the 1960s to 25 kg in the late 1990s (WARDA 2003) with a potential for increase in years to come.

Nigeria with all ecologies in the country suitable for rice cultivation has the capacity to be self-sufficient in rice production. The comparative resource advantage in terms of favourable climatic, soil and ecological conditions for production of rice also put Nigeria in a better position for self-sufficiency in rice production. Rice is grown in under the upland rain fed, inland shallow swamps, deep water and lowland irrigated production systems (Olayemi 1997; Oladele and Wakatsuki 2010). It is estimated that the potential areas for lowland rice production is between 4.6 and 4.9 million ha with only 1.7 million ha under cultivation (Imolehin and Wada, 2000). However, there has not been any improvement in the development of the vast area of lowland suitable for rice production in Nigeria. Researchers have conducted researches on effective utilization of the lowlands to improve rice production in Nigeria to a sustainable level. It was reported that the failure to effectively utilise the lowland for rice production was due to lack of understanding of lowland ecosystems. Buri *et al*. (2000) reported that lowlands receive eroded and transported material from adjacent uplands resulting in variations in nature and character with respect to both available and total nutrient contents. Sawah as a viable option for the development of these lowlands was introduce to Nigeria. Sawah refers to a levelled and bounded rice field with inlet and outlet for irrigation and drainage (Wakatsuki *et al.* 1998).

Sawah is a multifunctional constructed wetland characterised by geological fertilization process and nitrogen fixation which compensate for nutrients losses. 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 1986 (Hirose and Wakatsuki 2002). This was followed by on-farm adaptive research and participatory trials between 1986 and 1990 by

Japanese researchers. Effectively, the dissemination of the sawah technology took off in 2001 from villages previously identified in a diagnostic survey (Oladele and Wakatsuki 2010). To date, sawah technology has covered states in all the 6 geopolitical zones of Nigeria.

Various socio-economic studies have been conducted in order to strengthen the adoption and sustainable use of sawah technology in Nigeria. These included Oladele Wakatsuki (2008), Oladele Wakatsuki (2010), Fu *et al*., (2009), Fashola *et al*., (2006), Ademiluyi *et al*., (2008) and Alarima *et al*., (2011a). Till date, not much has been done on the fertility and nutrient management of sawah. In our previous study (Alarima *et al*., 2011b), we evaluated the basic physico-chemical and geochemical properties of the sawah soils in Nigeria, where we reported that sawah soils in Nigeria are low in basic nutrient fertility parameters. However, little information is available on sawah soils potential in providing the micronutrients required for rice production. This study therefore aims at investigating the micronutrients availability of the sawah soils in Nigeria. This will provide basic information for sustainable management of sawah soils in Nigeria in order to meet up with the desired increase in rice production and to address the rice demand and consumption among Nigerians.

8.2. Materials and Methods

Laboratory Analysis

Available Zn, Cu, Fe, Ni and Mn were extracted in DTPA-TEA (diethylene triamine pentaacetic acid – triethanolamine, pH 7.3) solution (Lindsay and Norvell, 1978, Reed and Martens 1996). Available Zn, Cu, Fe, Ni and Mn were determined using an inductive coupled plasma atomic emission spectrophotometer (Shimadzu ICPE 9000, Kyoto, Japan).

Statistical analysis

Statistical analysis was performed to determine the relationships between the soil fertility characteristics. Correlation analysis was used to determine the relationships that existed among soil fertility properties using the Statistical Package for Social Science (SPSS).

8.3. Results

Available Micronutrients

Table 1 shows the distribution of available micronutrients in sawah soils in Nigeria. Topsoil (0-15 cm) avail. Cu ranged between 0.43 and 4.09 mg kg^{-1} with a mean value of 1.90 mg kg^{-1} (SD = 1.04). Available Cu decreased with increasing depth (Fig 2) in most study sites but erratic in some sites. Avail. Cu level was high across all the sawah sites in Nigeria. Available Zn ranged between 0.07 and 5.83 mg kg^{-1} with a mean of 1.02 mg kg^{-1} (SD = 1.53). Avail. Zn was low with majority of the sites sampled for the study had values lower than the soil critical level of 0.83 necessary for rice production as proposed by Randhawa and Takkar (1975). Avail. Zn decreased with increase in depth but showed increase with depth in ILA 2. Topsoil avail. Fe ranged between 41.41 and 451.03 mg kg^{-1} with a mean of 199.09 mg kg^{-1} (SD = 129.37). As shown in Fig 2, avail. Fe mostly decreased with increase in depth but showed erratic distribution in few sites. Most of the sites had values falling within the range of 70-300 mg kg^{-1} of avail. Fe with only few sites have values below 70 mg kg^{-1} and values above 300 mg kg^{-1}. Topsoil avail. Mn values ranged between 9.27 and 99.12 mg kg^{-1} with a mean of 52.59 mg kg^{-1} (SD = 27.80). Avail. Mn mostly decreased with increase in depth but showed erratic distribution in some sites. There are however few cases of increase in values with increasing depth as were observed in EJT 1 and ILA 2. Avail. Ni values ranged between

0.08 and 1.56 mg kg^{-1} with a mean of 0.57 mg kg^{-1} (SD = 0.36). Avail. Ni mostly decreased with increase in depth but showed fluctuated with increase in depth in some sites.

Table 1. Topsoil Micronutrients of Sawah soils in Nigeria

Site	Available Micronitrients					Total elements			Total Elemental Oxides								CIA
	Cu	Fe	Mn	Ni	Zn	Zn	Cu	Ni	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	
	(mg kg-1)					(ppm)			(%)								
AKR 1	2.82	275.60	49.33	1.56	5.83	38.80	16.10	27.00	8.96	8.03	0.10	0.45	1.09	0.58	0.56	0.07	80.07
AKR 2	1.88	84.84	31.84	1.11	4.68	49.80	22.50	39.80	13.61	9.18	0.27	0.70	1.83	0.62	0.93	0.23	80.09
EJT 1	1.82	425.05	51.09	0.57	1.20	22.40	11.50	20.10	8.87	1.48	0.03	0.13	0.19	0.21	0.99	0.05	86.45
EJT 2	0.49	94.24	66.31	0.32	0.23	13.30	6.30	6.60	2.60	1.05	0.04	0.07	0.12	0.18	0.42	0.01	78.40
EMR 1	2.36	186.08	88.56	0.36	0.28	18.40	12.40	11.40	7.72	1.74	0.04	0.12	0.25	0.33	1.31	0.02	80.39
EMR 2	2.67	186.30	62.03	0.37	0.53	18.60	12.40	14.40	7.85	2.58	0.03	0.12	0.21	0.26	0.84	0.02	85.66
ETS 1	2.84	106.77	71.04	0.78	0.26	17.00	13.30	17.70	6.40	0.96	0.04	0.11	0.15	0.21	1.14	0.02	81.13
ETS 2	3.27	79.51	80.74	0.52	0.15	23.10	21.50	32.70	13.63	2.07	0.04	0.17	0.20	0.26	1.63	0.03	86.71
ILA 1	2.99	451.03	97.52	0.89	1.09	25.70	15.20	22.70	6.10	3.13	0.05	0.13	0.17	0.22	0.29	0.04	90.03
ILA 2	2.40	63.05	24.61	0.46	0.26	22.10	20.60	18.30	7.87	4.21	0.07	0.19	0.20	0.23	0.51	0.04	89.26
ILA 3	4.09	358.08	61.44	0.93	1.32	25.30	20.50	27.90	6.91	1.85	0.04	0.14	0.20	0.24	0.32	0.03	90.09
NSF 1	0.43	41.41	9.27	0.08	0.07	11.50	5.90	3.30	2.89	0.49	0.02	0.06	0.09	0.19	0.81	0.01	72.58
SHB 1	1.06	270.58	27.87	0.52	1.32	16.40	5.50	8.70	5.34	0.90	0.02	0.08	0.08	0.18	0.82	0.02	83.10
ZNK 1	0.54	175.52	12.39	0.18	0.07	17.00	3.40	8.30	10.38	1.77	0.03	0.16	0.34	0.71	3.96	0.01	67.45
ZNK 2	0.69	141.13	15.76	0.29	0.21	16.20	6.30	4.90	8.37	1.37	0.03	0.14	0.42	0.73	2.76	0.01	68.18
ISH 1	1.25	285.94	67.93	0.71	0.62	22.50	6.90	12.80	6.58	2.34	0.03	0.21	0.22	1.22	0.40	0.04	78.24
ISH 2	2.39	283.08	62.18	0.80	1.07	27.40	12.00	19.10	9.11	3.15	0.02	0.28	0.22	1.24	0.67	0.04	81.00
SHE 1	1.07	76.32	45.83	0.26	0.08	13.20	9.20	6.40	4.96	1.56	0.18	0.08	0.26	0.31	1.17	0.01	74.08
SHE 2	1.41	51.97	27.00	0.24	0.07	16.30	7.30	12.60	7.32	1.41	0.03	0.11	0.29	0.31	1.18	0.01	80.53
ETD 1	1.53	345.41	99.12	0.54	1.09	19.60	9.80	14.40	6.74	2.50	0.04	0.11	0.10	0.17	0.36	0.04	91.50
Mean	1.90	199.09	52.59	0.57	1.02	21.73	11.93	16.46	7.61	2.59	0.06	0.18	0.33	0.42	1.05	0.04	81.25
Standard	1.04	129.37	27.80	0.36	1.53	9.03	5.87	9.76	2.83	2.25	0.06	0.15	0.41	0.33	0.89	0.05	6.93

Correlation analysis between study parameters

Correlation analysis shown in Table 2 reveals that there is positive significant relationship between available Cu and total Cu (r = 0.82), total Ni (r = 0.73), total Zn (r = 0.44), CIA (r = 0.70) and clay (r = 0.71). There is however a negative significant relationship between avail Cu and pH (r = -0.56) and sand (r = -0.57). The study also revealed that there is a significant relationship between avail. Fe and CIA (r = 0.48) and pH (r = -0.51). A positive significant relationship exists between avail. Mn and CIA (r = 0.62) while a negative relationship exist with K2O (r = -0.46) and pH (r = -0.65). The result also shows that Avail. Ni is significant related to total Ni (r = 0.75), ex. Ca, (r = 0.46) ex. Mg (r = 0.51) and Ex. Na (r = 0.48). Avail Ni also has a significant relationship with avail. P, (r = 0.56) TC, (r = 0.68) TN (r = 0.69) and clay (r = 0.49). The result further shows that avail Zn is significantly related with total Zn (r = 0.87), ex. Ca, (r = 0.71) ex. Mg (r = 0.78) and Ex. Na (r = 0.71). Avail Zn also has a significant relationship with avail. P, (r = 0.76) TC, (r = 0.76) TN (r = 0.77) and clay (r = 0.44).

Table 2. Correlation Coefficient between Micronutrients and other Fertility Parameters

	Avail. Cu	Avail. Fe	Avail. Mn	Avail. Ni	Avail. Zn
Total Zn	0.44	0.21	0.08	0.83	0.87
Total Cu	0.82	0.04	0.30	0.60	0.44
Total Ni	0.73	0.21	0.29	0.75	0.63
Al_2O_3	0.37	-0.02	-0.02	0.35	0.38
Fe_2O_3	0.30	0.04	-0.03	0.75	0.88
MnO	0.03	-0.29	-0.13	0.36	0.56
MgO	0.21	-0.04	-0.12	0.70	0.84
CaO	0.07	-0.15	-0.24	0.58	0.83
Na_2O	-0.14	0.10	-0.12	0.24	0.18
K_2O	-0.37	-0.30	-0.46	-0.42	-0.26
P_2O_5	0.16	-0.01	-0.06	0.59	0.74
CIA	0.70	0.48	0.62	0.38	0.13
PH H2O	-0.56	-0.51	-0.65	-0.26	0.11
Ex. Ca	0.02	-0.12	-0.17	0.46	0.71
Ex. K	0.27	0.17	0.05	0.25	0.22
Ex. Mg	0.03	-0.10	-0.25	0.51	0.78
Ex. Na	0.08	-0.13	-0.09	0.48	0.71
Avail. P2O5	0.08	0.02	-0.08	0.56	0.76
TN	0.24	0.28	-0.02	0.69	0.77
TC	0.23	0.35	-0.03	0.68	0.76
Clay	0.71	0.12	0.22	0.49	0.44
Silt	0.25	0.25	0.29	0.05	-0.05
Sand	-0.57	-0.23	-0.32	-0.31	-0.22

8.4. Discussion

Micronutrients availability in sawah soils in Nigeria varied from deficient, moderate, high and in few cases toxic. The results of our chemical analyses indicated that both total Cu and avail. Cu concentrations varied throughout the study area. Avail. Cu level was generally high across all the sawah sites in Nigeria with all the sites having topsoil values higher than the critical level of 0.2mg Cu kg^{-1} as recommended by Ponnamperuma *et al* (1981). The high avail Cu in this study is related to the abundance of Cu in the parent material of the soil. A significant correlation exists between avail. Cu and total Cu. The result of this study is in accord with a previous report of Buri *et al*., (2000) who reported that avail. Cu is not yet a limiting factor for lowland rice production in West Africa. Avail. Zn was generally low across all the sawah soils in Nigeria. The low content of Zn may be due to prevalence of parent material with low Zn content. Low level of Zn may also be due to low content of TC and TN in the study sites. The contribution of soil organic matter content towards Zn was higher as compared to soil pH in this present study. There was a significant correlation between organic matter (TC: $r = 0.68$; TN: $r = 0.69$) and avail. Zn. Increased levels of organic matter, increase exchangeable and organic fractions of Zn and decrease oxide fractions of Zn in soil because of reducing conditions to enhance Zn availability (Behera *et al*, 2011). Positive and significant correlation between soil organic matter and total Zn indicates that the total Zn content in soil increases with the increase in soil organic matter. The low content of avail. Zn may also be due to the sandy nature of the soils. A significant relationship exists between clay content and Zn. Rautaray *et al*. (2003) reported that problem of Zn deficiency is more acute in sandy acid soils having low organic matter content and low level of available plant nutrients. Avail. Fe content was moderate to high across all the sites in this study with most of the sites having values falling within the range of 70-300 mg kg^{-1} of avail. Fe required for normal rice growth as proposed by Tanaka and Yoshida (1970). Although few sites show deficiency of avail. Fe with values below 70 mg kg^{-1} and few site had values above 300 mg kg^{-1} which may result in toxicity. There is a negative significant correlation between pH and avail. Fe which means that the lower the pH, the higher the content of avail. Fe. Avail. Fe has no significant relationship with other fertility parameters except pH. The high content of Fe may also be due to leaching experience as a result of high rainfall and the sandy nature of the soils. With high rainfall, basic nutrients such as calcium and magnesium in the soil are leached from the soil and are replaced by acidic elements such as aluminum and iron which results in high Fe content. Buri *et al*. (2000) reported high avail. Fe in highly leached and sandy soils of West Africa. Available Mn is moderate across all sawah sites in Nigeria. Although there is no significant relationship between avail. Mn and total elemental MnO, Mn availability as reported by other authors may be influenced basically by the redox potential of the sawah soils under submergence condition. Buri *et al* (2000) reported that under submerged conditions, soil solution Mn increases and slight increase in pH with flooding condition enhancing further increase in the concentration of Mn in soil solution. Sawah soils in Nigeria showed moderate level of avail. Ni. Avail Ni had significant relationships with total Ni, exchangeable cations, TC, TN, avail. P and clay which show the importance of other fertility parameters on micronutrients.

8.5. Conclusion

The result of this study has provided the basic information on micronutrients availability and a baseline study for further investigations that could contribute to the desired increase in rice production. The results of the present study showed that sawah soils in Nigeria are deficient in Zinc, moderate in Cu, Ni and Mn. Available Fe was found to be moderate, however, Fe toxicity was observed in some sites. Although, average Zn value was above the critical level of for rice production, majority of the sawah soils in Nigeria had Zn value below the critical level. Availability of micronutrients has been found to be influenced by total micronutrient organic matter content. The roles of other factors such as redox potential and pH influencing micronutrient availability in submerged soil condition could not be ascertained in this study. A further study to investigate the roles of redox potential and pH on the micronutrient availability in sawah soils in Nigeria is recommended.

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CHAPTER 9

Determinants of Adoption of Sawah Rice Technology among Farmers in Ashanti Region of Ghana.

9.1. Introduction

The agriculture sector in Ghana continues to serve the traditional role of providing food security, supplying raw materials to industry, creation of employment opportunities, and the earning of foreign exchange. This sector is still the largest foreign exchange earner and the largest contributor to Ghana’s Gross Domestic Product (GDP). Its dominant role in the economy makes this sector a target for national development programmes and strategies (Kranjac-Berislavjevic 2000; CARD, 2010). Ghana is 51% self-sufficient in cereal production while rice self-sufficiency is estimated at 30% in 2009 (CARD, 2010). Rice is an important cereal to Ghana’s economy and the second most important cereal next to maize in terms of consumption. Rice constitutes 58% of all cereal imports. The rice import bill is estimated at US$500 million annually and has become a source of concern to government. Ghana’s increasing dependency on rice imports and the consequent negative impact on foreign exchange balances will continue to increase if there is no significant strategy and policy shift in support of the local rice industry (CARD, 2010).

Ghana was found to have a comparative advantage in the production of paddy rice over the other countries in the sub-region (Asuming-Brempong, 1998). Rain-fed rice contributes 84% of total current production, generating average paddy yields of 1.0- 2.4 metric tons per hectare. Irrigated production totals only 16%, but produces average paddy yields of 4.5 metric tons per hectare. Due to poor yields from rain-fed rice and the lack of irrigation facilities, domestic rice production has not grown as fast as domestic demand. As a result, rice imports from Thailand, Vietnam, the U.S., India and Pakistan have grown considerably to fulfil Ghana's increasing demand and preferences. From a steady level of 7-8 kilograms per year before 1990, per capita rice consumption increased to 11.5 kilograms per year on average during the 1990s and climbed considerably to 27 kilograms per year for the period from 2001-2005 (WARDA, 2008). Future increases are projected by the Ministry of Food and Agriculture (MOFA) based on a combination of overall population growth, rising income, and increasing urbanization. Based on demographic trends and income growth, Ghana's Ministry of Food and Agriculture estimates that demand for rice in Ghana will increase at a compound annual growth rate of 11.8% from 939,920 metric tons to 1,644,221 metric tons between 2010 and 2015.

In view of food security and foreign currency savings, increased production of domestic rice with higher competitiveness against imported rice is paramount to Ghana's agricultural sector development (JICA, 2007). Improvement in rice productivity potential will no doubt play a critical role in feeding the population that is expected to double during the next two decades. Therefore, there is a need to support farmers to increase rice productivity rather than acreage cultivated, if Ghana is to meet the short-fall in rice production.

In addressing the challenges faced by farmers in increasing rice production, sawah rice technology was introduced to farmers in Ghana. Sawah refers to levelled rice field surrounded by banks with inlet and outlet for irrigation and drainage. The introduction of sawah technology with soil improvement, water management and high yielding characteristics has been viewed as a strategy to increase and maintain rice production levels. Sawah as a low-cost innovation that is highly sustainable, not requiring large capital investments and relatively easy to implement can help poor farm households become more productive by improving the fertility of the soil and increasing yields (Wakatsuki, 2011).

Lowland sawah systems can sustainably produce more than 2 tonnes/ha paddy without any chemical fertilizer application (Hirose and Wakatsuki, 2002; Wakatsuki et al., 2009). In addition, lowland sawah systems can support rice cultivation continuously for decades, centuries or more without any fallow period (Wakatsuki, 2011).

According to Tsujimoto et al. (2009) sawah approach offers low-cost irrigation and water control for rice intensification with sustainable paddy yield of more than 4t/ha but with improved agronomic practices, such as the System of Rice Intensification (SRI) with the sawah systems, paddy yield can reach more than 10t/ha. The sawah approach involves site selection and site-specific sawah system design; skills for cost-effective sawah system development using a small hydro-power tiller; co-ordination of farmers' group formation and land tenure arrangements to sustain sawah development; sawah-based rice agronomy, including best variety selection and management to realize at least the sustainable paddy yield of more than 4t/ha, and establishment of institutional training and dissemination systems for sawah eco-technology transfer (Buri et al. 2009).

Various research programmes and extension projects have been carried out to improve the adoption and diffusion of sawah rice technology ranging from on-farm adoption trials, on the job training and workshops. This study intends to examine the determinants of adoption of sawah technology among the farmers in Ashanti region of Ghana. A wide range of variables influence adoption of such technology. It is important to understand the role of these factors to ensure the sustainable development and use of sawah technology. To achieve self sufficiency in rice production, sawah technology should be disseminated to farmers across all regions in Ghana and the implication is that, in disseminating sawah technology, policy makers must bear the major findings of this study in mind to enhance effective adoption.

9.2. Literature Review

Increasing agricultural productivity is critical to economic growth and development of any nation and this can be achieved through the introduction of improved agricultural technologies and management systems (Doss, 2006). Adoption of improved agricultural technologies has become a critical avenue for increasing productivity in developing countries (Mignouna et al, 2011), but is subject to various factors the farmers consider before the adoption. Adoption is the mental process an individual passes through from first hearing about an innovation to final adoption (Rogers, 2003). Adoption studies have consistently emphasized the importance of various farmer and farm characteristics in determining whether such technologies will be adopted. The decision of a farmer to adopt a technology is complex and involved two mutually exclusive processes; the first involves making the decision to adopt the specific technology in the first place, while the second involves deciding on the level or intensity of use of the same technology (Sall et al., 2000). According to Mcdonald and Brown (2000) farmers may reject or abandon many technologies, which have been proved useful, and adopt others in their place since they consider a variety of factors in deciding whether or not to adopt particular innovation. On the other hand, after adopting a technology, farmers also decide on the level at which they use the technology.

Quite a number of studies have been carried out to identify the factors that determine the adoption and the level of adoption of agricultural technologies. All these studies have reported both the farmers-specific factors, farm-specific factors, institutional factors, innovation-specific factors, economic factors and non-economic factors. Anderson and Thampapillai (1990) found that a wide variety of factors including land tenure arrangements, access to credit and farmers risk attitudes influence the rationality of adopting soil conservation practices among farmers. Hwang, et al. (1994) also reported that poor access to credit and lack of secure tenure, as well as low output prices, were limiting the adoption of soil conservation practices among farmers. Sall et al. (2000) reported that both farmers' perceptions, as well as farm and farmer characteristics, were found to be important in determining the decision to adopt and the intensity of adoption of the improved rice varieties. According to De Souza Filho et al. (1999), membership of farmers' organizations, contacts with nongovernmental organizations (NGOs), availability of family labour, soil conditions and farm size determine the level of adoption of agricultural technology. Faltermeier (2007) also reported that access to credit, project involvement, family land/ labour ratio, age, reported good results, as well as soil type and retention capacity influence the adoption decision of bunds in the lowland rice production systems.

Thapa and Rasul (2005) found that institutional support, including land tenure, extension services and credit facilities, productive resource base and the distance to the market and service centres were found to be the major factors influencing agricultural systems. Motivation by Governmental Organizations (GOs) and Non Governmental Organizations (NGOs), motivation by community members and farmers' groups, attendance in training, also determined the adoption of technology (Thapa and Rattanasuteerakul, 2011). According to Reimer et al. (2012), perceived high levels of relative advantage (e.g., reduced inputs, time-savings, and on-farm and environmental benefits), compatibility (with farm system and needs of producer), and observability (observing practice's advantages) are most important in increasing adoption of conservation practices. To He et al. (2007), farmers' educational background, active labour force size, contact with extension, credit obtained, assistance obtained, technical training received and positive attitudes towards technology are some of the variables that have positive effects on adoption of technology. Lapar and Ehui, (2004) reported that farmers who are more educated, have higher income, and have access to credit are more likely to adopt the dual-purpose forages. Adrian et al. (2005) found out that attitude towards agriculture technologies, perceptions of net benefit, farm size and farmer educational levels positively influenced the intention to adopt precision agriculture technologies.

9.3. Methodology

Study Area

Ghana is located on the west coast of Africa, about 750 km north of the equator 8 00 N, 2 00 W. The population in 2010 is estimated at 24,339,838, with a population growth rate estimated at about 1.8%. Ghana has a total area of 239,460 km^2 with land area of 230,020 km^2. Land use pattern is made up of arable land (6.26%), permanent crops (9.67%) and other (74.07%). The study was carried out in Ashanti region of Ghana. The Ashanti Region is centrally located in the middle belt of Ghana. It lies between longitudes 0.15W and 2.25W, and latitudes 5.50N and 7.46N. The region shares boundaries with four of the ten political regions; Brong-Ahafo in the north, eastern region in the east, central region in the south and western region in the south west. The region occupies a total land area of 24,389 km^2 representing 10.2 % of the total land area of Ghana. It is the third largest region after Northern (70,384 km^2) and Brong Ahafo (39,557 km^2) regions. The region has a population density of 148.1 persons per square kilometre, the third after Greater Accra and Central Regions. More than half of the region lies within the wet, semi-equatorial forest zone. Agriculture provides employment to more than half of the economically active population in the region. The major occupation in all the districts is agriculture/animal husbandry/forestry. The region has an average annual rainfall of 1270mm and two rainy seasons. The major rainy season starts in March, with a major pick in May. There is a slight drop in July and a pick in August, tapering off in November. December to February is dry, hot, and dusty. The average daily temperature is about 27 degrees Celsius. Much of the region is situated between 150 and 300 metres above sea level.

Sampling and Data Collection

Sites for dissemination of sawah technology were carefully selected based on the availability of inland valleys suitable for production. The availability of inland valley is a prerequisite for the adoption of sawah technology. Data used in this study were collected in the sawah sites within Ashanti region of Ghana namely: Adugyama, Amaekrom, Asuade, Baanekrom, Biemso 1, Biemso 2, Nsutem, Potrikrom and Sokwae. A list of rice farmers in the villages where sawah system was disseminated was compiled. A total of 108 sawah farmers were randomly selected from the population of 198. A well structured interview guide was used to elicit information from the farmers. The data for this study were obtained from a survey using face-to-face interview with the randomly selected sawah farmers in 2011.

Variable selection and Measures

Dependent variable

The dependent variable for this study is adoption of sawah technology. This is determined by listing all the aspect of sawah technology similar to Marenya and Barrett, (2007) and asked farmers to indicate their level of adoption. The aspects of sawah technology are bund construction, power tiller use and puddling, levelling, smoothening, nursery, canal construction, irrigation and flooding, dyke construction and use of sand bags. This was defined on a 3-point likert scale of full adoption (3), partial adoption (2) and discontinued/not adopted (1) following Alarima et al., (2011). Scale scores were computed by summing across responses to items in the scale.

Explanatory Variables and hypotheses

As suggested by literature (Amsalu and Graaff, 2007), adoption of agricultural technology is affected by social, economic and non-economic factors. The following are the explanatory variables that are hypothesised to influence adoption of sawah technology among the farmers in the study area. These variables ranged from personal factors, institutional factors, farming factors to the attributes of innovation (sawah technology) as shown in Table 1.

1. *Personal factors*

Age: This was measured in years as a continuous variable. It is hypothesised that young farmers have a greater chance of absorbing and applying new technology and older people will be less likely to adopt therefore age is expected to have significant influence on adoption.

Educational Level: This measures the level of education of the farmer. This was measured ordinally as: no formal education, primary education, secondary education, and Tertiary education. It is expected that farmers with higher levels of educational attainment are more likely to adopt new technologies than less educated farmers. Hence, it is expected that educational level has a significant impact on adoption of sawah technology.

Household Size: This measures the size of the family. Household size was determined by the actual number of persons in a household. A relatively large household size of the farmers could serve as a viable source of farm labour hence it is hypothesised that household size has a significant influence on the adoption of sawah technology.

Farm Size: Farm size measures the area of land put into sawah production. This was measured using a geographic positioning systems instrument (GPS) in hectares. It is expected that size of farm dedicated to sawah production will significantly affect level of adoption.

Years of experience: This measures the number of years farmers have been involved in rice production. It is expected that farmers with long years of experience in rice production will be in better position to adopt sawah technology and hence it is hypothesised that years of experience has a significant influence on the adoption of sawah technology.

Labour source: Labour source measures the source of labour available to the farmer. This was measured ordinally as: family labour, hired labour and combination of family and hired labour. It is expected that labour source will eventually affect the profit margin of the farmer. Thus, labour is expected to have a significant influence on the adoption of sawah (Marenya and Barrett, 2007).

Income: Income was assessed as the total amount realised from both on-farm and off-farm activities in a given year in the local currency (Cedi). The local currency was converted to the dollar using the prevailing exchange rate at the time of this survey. Higher level of the income implies the ability to invest in sawah technology especially the purchase of tools like power tiller which is the only power-driven tool that is effectively being used for sawah activities and other inputs. A significant relationship is expected between adoption of sawah technology and income.

2. *Institutional factors*

Contact with Extension Agents: This is measured as a dummy variable which measures whether or not the farmer has contact with extension agents (1 if yes, 0 if no). Farmers who have frequent contacts with extension agents and easy access to information about sawah technology can regularly upgrade their knowledge of technology. They will be able to relay their problems and challenges they face to the extension agents thereby improving on their farming activities. It is expected that contact with extension agents will significantly influence adoption.

Attendance in previous Sawah training: This is measured as a dummy variable which measures whether or not the farmer has attended a previous training on sawah development (1 if yes, 0 if no). As in the case of education, farmers who have attended previous trainings on sawah technology will have a better understanding of sawah and hence it will have significant influence on their level of adoption.

Membership of farmers associations: This is measured as a dummy variable which measures whether or not the farmer belongs to a farmers' association (1 if yes, 0 if no). Farmers in rural areas form farmers associations and groups. This helps them in accessing loans and credit facilities and other farm inputs such as fertilizer, seed, and simple farm tools from the government and other Non Governmental Organizations (NGOs), hence it is expected to have significant effect on adoption.

3. *Farming factors*

Land tenure: Land tenure measures status of land ownership. This was measured ordinally as inheritance for those that use the land belonging to their family and rentals for those that hired the land they use for sawah development. In the literature, there are divergent views on the importance of tenural arrangement as it affects adoption decisions. Some reported that land tenure has effect on adoption (Oladele and Wakatsuki, 2009) while other reported no effect on adoption (Gavian and Ehui, 1999) hence it is difficult to predict whether land tenure will have a significant effect on adoption. However for the purpose of this study, it is hypothesised that land tenure will significant influence adoption.

Yield: The yield was determined by measuring in kilogram, the paddy harvested from the cultivated sawah area. High yield from sawah farm is expected to increase the level of adoption of sawah technology. A significant relationship is expected between adoption of sawah technology and yield.

4. *Attributes of innovation*

This was determined by asking the farmers to indicate the attribute of sawah technology that motivated them to adopt the technology. This is measured as a dummy variable as 1 if yes, 0 if no for the identified attributes of sawah which include high yield; disease and pest control; fertilizer management; water management; weed control; good tillering (Wakatsuki, 2011;

Alarima et al., 2011). It is hypothesised that positive perception of these attributes will significantly influence adoption.

Data Analysis

The obtained data were subjected to descriptive and inferential statistics. Descriptive statistics were used to analyze the personal and farming characteristics of the farmers. Regression analysis was used to determine the relationships between adoption and predictor variables as specified in the equation below:

$$ADOP = a + \beta \text{ x } AGG + \beta \text{ x } EDD + \beta \text{ x } HHSIZ + \beta \text{ x } FSZ + \beta \text{ x } YREXP + \beta \text{ x } LABR + \beta \text{ x } INCM + \beta \text{ x } EXTN + \beta \text{ x } TRN + \beta \text{ x } ASSM + \beta \text{ x } LTNR + \beta \text{ x } YELD + \beta \text{ x } ATTR$$

Table 1 also shows the detail description of the variables in the regression equation.

9.4. Result and Discussion

Descriptive Statistics

The study as shown in Table 1 reveals that the adoption score range between 10 and 24 with a mean of 17.80 (SD = 3.75). The level of adoption among the farmer is considerably high which may be due to benefits the farmers derived from using sawah technology. Age of farmers ranged between 26 and 62 years with a mean of 39.96 (SD = 7.69). Majority of the farmers have secondary education which means they can read and write while the mean household size is 6 (SD = 3.44). The average farm size of the respondents is 0.37 ha (SD = 0.28) while mean years of experience in rice production is 11.93 years (SD = 8.79). Average annual income of farmers is 3043.80 Ghana Cedi (2029.2 USD) (SD = 1728.38). Farmers mostly use family labour for their farm activities while average rice yield of the farmers is 3406kg per hectare of sawah field. Most farmers in the study area rent the land they use for sawah rice production. This study revealed that there is always a tenancy arrangement between the tenant farmers and the land owners before the land is used. This arrangement is considered as mutually beneficial for both landlord and tenant and the nature of agreement is believed to be fair on the part of both parties. The duration of the agreement ranges from 5-15 years which is renewable.

Table 1. Description of the variables of the study

Acronym	Description	Measurement	Min	Max	Mean	SD
ADOP	Adoption level	3-point likert scale of full adoption (3), partial adoption (2) and discontinued/not adopted (1)	10.00	24.00	17.80	3.75
Personal factors						
AGG	Age	Continuous variable in years	26	62	39.96	7.69
EDD	Educational Level	No formal education (1), Primary education (2), secondary education (3), and Tertiary education (4).	Mostly Secondary Education			
HHSIZ	Household size	Number of persons in the household	3	16	6.11	3.44
FSZ	Farm Size	Continuous variable in hectares	0.01	1.00	0.37	0.28
YREXP	Years of experience	Continuous variable in years	1	34	11.93	8.79
LABR	Labour source	Family labour (1), hired labour (2) and both family and hired labour (3)	Mostly family labour			
INCM	Income	Continuous variable in Cedi	630.00	7303.00	3043.80(2029.2 USD)	1728.38
Institutional factors						
EXTN	Contact with Extension Agents	Dummy (1 if yes, 0 if no)	0	1	0.96	0.19
TRN	Attendance in training on Sawah	Dummy (1 if yes, 0 if no)	0	1	0.65	0.48
ASSM	Membership of farmers associations	Dummy (1 if yes, 0 if no)	0	1	0.89	0.31

Farming factors						
LTNR	Land tenure	Inheritance (1) and rentals (2)		Mostly by rent		
YELD	Yield	Continuous variable in kg	720	8040	3406.15	1940
ATTR	**Attributes of innovation**					
High Yield		Dummy (1 if yes, 0 if no)	0	1	0.96	0.20
Disease and pest control		Dummy (1 if yes, 0 if no)	0	1	0.96	0.20
Fertilizer management		Dummy (1 if yes, 0 if no)	0	1	0.94	0.24
Water management		Dummy (1 if yes, 0 if no)	0	1	0.92	0.27
Weed control		Dummy (1 if yes, 0 if no)	0	1	0.92	0.27
Good tillering		Dummy (1 if yes, 0 if no)	0	1	0.81	.039

Adoption Regression Results

Table 2 reports the regression result for the variable that determined the adoption of sawah technology among the respondents. The result of this study reveals that age has a negative impact on adoption of sawah technology, which suggests that the probability of adoption of sawah technology is higher among the young farmers than older farmers. This could be because of resistance to change by aged farmers (Adesoji, *et al* 2006; Ajayi, 1995). According to Marenya and Barrett (2007) older farmers are less likely to adopt technology because their planning horizon shrinks and their incentives for them to invest in future productivity of their farms diminish. Older farmers find it difficult to change from their former way of doing thing for a new method. The younger farmers may be inquisitive, wanting to learn more, hence increase their level of adoption. This may also be connected with the strenuous nature of sawah technology which may need relatively healthier and stronger younger farmers to adopt than older counterparts (Oladele and Wakatsuki, 2009). Education has a positive significant relationship with adoption of sawah technology suggesting that more educated farmers are more likely to adopt sawah technology than less educated farmers. According to Chianu and Tsujii (2004) sited from He et al. (2007), targeting young farmers and a systematic increase of farmers educational attainment can increase probability of agricultural technology adoption. Year of experience in rice production has a positive significant relationship with adoption of sawah technology. The knowledge gathered by farmers in long years of rice production can also be useful in the adoption of sawah technology. However contrary to expectations, household size, farm size, labour source and income do not significantly influence farmers' adoption of sawah technology.

As expected, contact with extension was found to have a significant positive effect on adoption of sawah technology, meaning that farmers who have contact with extension agents and institutions are likely to adopt sawah technology than those that do not have contact with extension agents. Contact with extension agents allows farmers greater access to the latest information as regard agricultural practices and also avail them opportunity to participate in field demonstration hence increase the probability of adoption of any agricultural technology (He et al., 2007; Oladele and Wakatsuki, 2009). As hypothesised, attendance in previous sawah training was also found to have a significant positive effect on adoption of sawah technology. Training farmers on how to construct bunds, canals, sawah basins and the operation of power tiller for instance is expected to have a positive effect on the adoption of sawah technology. Contact with extension and attendance in previous trainings can provide farmers with knowledge and information on sawah technology, which can lead to higher competence among the farmers (Oladele and Wakatsuki, 2009). However, contrary to expectations membership of farmers' association does not significantly influence farmers' adoption of sawah technology.

As hypothesised, land tenure has a significant relationship with adoption of sawah technology. Land as an important factor of production needs to be secured due to the critical role it plays in adoption. Emanating from this study is the fact that land tenure arrangements significantly affect the adoption of sawah technology by farmers. Land tenure security determines whether people will invest in and adopt sawah technology and can therefore be regarded as an important ingredient in adoption of sawah technology. According to Oladele and Wakatsuki (2009), the probability of adoption of sawah technology increases if the plot of land used for sawah is acquired through inheritance, by purchase, having long tenancy period and if the rent paid for the land is low. Yield realised by farmers from their farm is also found to have a significant positive effect on adoption of sawah technology. This result is corroborated by Ali-Olubandwa (2010) who reported a statistically significant relationship between adoption and yield among small scale farmers in western province of Kenya. According to Wakatsuki (2011), sawah systems can sustain paddy yields higher than 4 t/ha through various macro-scale natural geological fertilization processes and micro-scale mechanisms to enhance the supply of various nutrients. With the application of advanced agronomic practices, sustainable paddy yields above 10 t/ha can be achieved in lowlands with quality sawah and soil and water management.

The result further shows that attributes of sawah technology as hypothesised were found to have a significant positive effect on adoption of sawah technology. These attributes include high yield, disease and pest control, fertilizer management, water management, weed control and good tillering. As mentioned above, farmers are sure of paddy yields higher than 4 t/ha and when advanced agronomic practices are adopted, the yield may rice to 10t/ha. Sawah system encouraged the growth of various aquatic algae and other aerobic and anaerobic microbes in addition to rice growth, which increase nitrogen fixation in the sawah system through increase of photosynthesis as multi-functional wetlands. The result of this study is also in agreement with Fu *et al.* (2009) who reported that higher yield, better water and weed control, have been recognized by participating farmers as the factors affecting the adoption of sawah technology among the Nupe farmers in Nigeria.

Table 2. Regression between Adoption and Predictor variable

Variables	Unstandardized Coefficients (B)	Standardised Coefficients (β)	S.E.	t-ratio (B/S.E.)
AGG**	-17.766	-1.261	4.275	-4.156
EDD**	3.305	0.454	0.854	3.869
HHSIZ	0.139	0.183	0.115	1.202
FSZ	1.578	0.131	1.541	1.024
YREXP**	2.714	0.445	0.873	3.109
LABR	-0.237	-0.017	1.673	-0.141
INCM	0.026	0.081	0.053	0.500
EXTN**	0.160	0.436	0.049	3.240
TRN*	5.070	0.497	1.768	2.869
ASSM	0.436	0.104	0.597	0.730
LTNR**	3.404	1.296	0.838	4.062
YELD*	0.152	0.242	0.079	1.927
ATTR*	2.855	0.334	1.031	2.770
Constant*	-6.062		3.211	-1.888
R =	0.86			
R Square =	0.74			
Adjusted. R Square=	0.62			
df =	13/30			
F value =	6.42			
Sig. =	0.00			

*: significant at P<0.05, **: significant at P<0.01

9.5. Conclusion

This study was undertaken to improve the understanding of the factors that determined the adoption of sawah technology among farmers in Ashanti region and to also promote further adoption among other farmers in Ghana. The results of the study will help prioritize the factors to be considered to further increase the adoption of sawah technology in the drive to attain self sufficiency in rice production in Ghana. The result of this study reveals that age, education in addition to year of experience in rice production influence the adoption of sawah technology among the farmers. The study also revealed that contact with extension agents and attendance in previous trainings significantly influence adoption. The study revealed that land tenure arrangements significantly affect the adoption of sawah technology by farmers. Yield was also found to have a significant effect on adoption of sawah technology. The study further revealed that the benefits of sawah technology must be clearly perceived by the farmers in other to improve on the adoption of sawah technology. Further dissemination and adoption of sawah technology must therefore bear in mind the findings of this study.

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CHAPTER 10

Soil property change during the period of 2000 - 2011 across land use types along the topo-sequeces in inland valley watershed of Ashanti region, Ghana.

10.1. Introduction

The economy of Ghana is largely agriculture-based with agriculture contributing 38 % of the Gross Domestic Product (GDP) (the largest contributor to Ghana's GDP), 75 % of the country's export earnings and 60 % of the employment (World Bank 2006). About 45 % of the total population is employed in the agriculture sector and more than 90 % of the food need of Ghana is met by this sector (World Bank 2006). Its dominant role in the economy makes this sector a target for national development programmes and strategies (Kranjac-

Berislavjevic, 2000; CARD, 2010). The agriculture sector of Ghana paraded an array of crops ranging from cereals, tubers, legumes and cash/tree crops.

There has been no significant growth in the yields of most crops in last 10 years in Ghana, and the yields of certain crops (e.g., rice, sorghum, millet, cassava, yam, cocoyam, and beans) have shown declines during this period (Diao and Sarpong, 2007). Although a lot of factors are responsible for this decline, however, poor fertility of soils in Ghana may as well be a major factor to contend with. As reported by previous authors, Ghanaian soils as in other parts of West Africa are characterized by poor fertility (Issaka et al., 1996; Buri et al., 2000; Anann-Afful, et al., 2004). The poor level may be as a result of continuous use and lack of proper soil fertility management planning for a sustainable production, resulting in a continuous depletion and degradation of the soils. Soil degradation is a widespread and serious phenomenon in Africa. Two thirds of land used in Africa for cultivation is affected by land degradation and each year between 5 and 6 million hectares suited for agricultural production are permanently lost due to soil degradation (Johnson et al. 2006). Eswaran et al., (2005) reported that degraded soils are becoming more prevalent in Africa due to intensive use, low inputs and poor management by growing population.

Loss of soil functions due to soil quality degradation impacts Africa's agricultural viability and food security (Moebius-clune et al., 2011). Ghana is one of the countries in Africa which is most severely affected by soil degradation. The continuous increase in population in Ghana puts a lot of pressure on the land especially with the prevalent slash and bush agricultural practice (Anann-Afful, et al., 2004) resulting in increased opportunity for land degradation and depletion. Soil degradation is evident in all the agro-ecological zones of Ghana (Asiamah, *et al*., 2000, Quansah *et al.,* 2002) and therefore a major constraint to the attainment of the desired growth rate in the agricultural sector (MoFA, 1998). Diao and Sarpong (2007) reported that soil degradation reduces agricultural income in Ghana by a total of US$4.2 billion over the period 2006–2015, which is approximately five percent of total agricultural GDP in these ten years.

A thorough understanding of the level and causes of soil depletion in Ghana is very important with special attention given to the Inland Valleys (IVs). IVs constitute the upper part of the river network. IVs offer a considerable potential for agricultural intensification and diversification due to their higher water availability and potential natural soil fertility. IVs topo-sequence includes the valley bottom, hydromorphic fringes, slopes, plateaux, and ridges. These variations along the topo-sequence create a means of diversification of crops which can help increase productivity. According to Wakatsuki et al., (2001), the potential area for small-scale irrigated rice in inland valley bottom in Ghana is estimated at 700,000 ha. IVs also provide efficient and suitable environment for other crops at the fringes, slopes, and ridges. Understanding the level and rate of decline in soil quality will help provide a basis for soil fertility management planning for sustainable crop production of the IVs. This will also help in preventing IVs from eventual soil degradation found in other parts. Anan-Afful et al., (2004) presented the dynamics and characteristics of soils along the topo-sequence in an inland valley watershed in Ashanti region. This study therefore aims to examine the changes that have occurred in soil chemical parameters along the topo-sequence in the watershed between 2000 and 2011. The study focused on cocoa farm (CF), fallow land (Fallow), traditional rice farming (TR) and sawah (Sawah) along the topo-sequence. Sawah refers to levelled rice field surrounded by banks with inlet and outlet for irrigation and drainage. The basic elements of sawah system include improved irrigated rice basins, seedbed preparation, transplanting and spacing of seedlings, fertilizer application and most importantly, appropriate water management. Sawah rice cultivation was introduced to the inland valley watershed of Ashanti region in 1999.

10.2. Material and Methods

Description of the study area

The study was carried out in Ashanti region of Ghana. The Ashanti Region is centrally located in the middle belt of Ghana. It lies between latitudes 5.50N and 7.46N and longitudes 0^{o} 15'W and 2.25W. The site is located on 6^{o}55'N and 1^{o}55'W at elevation of 200-450m above the sea level (Wakatsuki et al., 2001). The mean annual rainfall of the study area is about 1,300mm-1,400mm. The major rainy season starts in March, with a major pick in May. There is a slight drop in July and a pick in August, tapering off in November. The annual mean temperature of the study site is 25.2^{o}C. Soils of CF and Fallow belong to the Nzima series of Ferric Lixisols, while soils of TR and Sawah belong to the Oda series of Eutric Gleysols (IUSS Working Group WRB 2006). They are poorly drained and are intermittently flooded for a certain period within the year. Detail description of the study area was reported by Anann-Afful, et al. (2004).

Soil sampling and laboratory analyses

In 2011, soil samples were collected at the same fields where soil samples were collected or point as close as possible to the original point where Annan-Afful, et al., (2004) collected in year 2000 (Fig. 1). This was done with the assistance of the local farmers that participated in the soil sampling in year 2000. Soil samples were collected across the soil depth of 0-20cm, 20-40 cm and 40-60cm in CF, Fallow, TR and Sawah.

Soil samples were air-dried, ground and pass through a 2mm mesh sieve. Soil pH H_2O was measured with a pH meter (Horiba Limited, Kyoto Japan) according to the method recommended by IITA (1979) and Mclean (1982) with a ratio of 1:2.5. Total carbon (TC) and total nitrogen (TN) were determined by dry combustion method with NC analyzer (Sumigraph NC-22; Sumika Chemical Analysis Service, Tokyo, Japan). Exchangeable cations (ex. Ca, ex. Mg, ex. K and ex. Na) were extracted with 1 *M* neutral ammonium acetate. Ex. Ca and ex. Mg were determined using inductivity coupled plasma-atomic emission spectroscopy (Shimadzu ICPE 9000, Kyoto, Japan). Ex. K and ex. Na were determined using atomic absorption spectrophotometer (AA-680; Shimadzu, Kyoto, Japan). Available phosphorus content was determined by Bray 1 method (Bray1-P, Bray and Kurtz 1945). Available micronutrients, Cu, Fe, Mn, Ni and Zn were extracted with DTPA-TEA (diethylenetriamine pentaacetic acid-Triethanolamine, at pH 7.3 using soil solution ratio of 1 : 2 and shaking time of two hours (Reed and Martens, 1996). DTPA Cu, Fe, Mn and Zn were determined using inductivity coupled plasma-atomic emission spectroscopy (Shimadzu ICPE 9000, Kyoto, Japan).

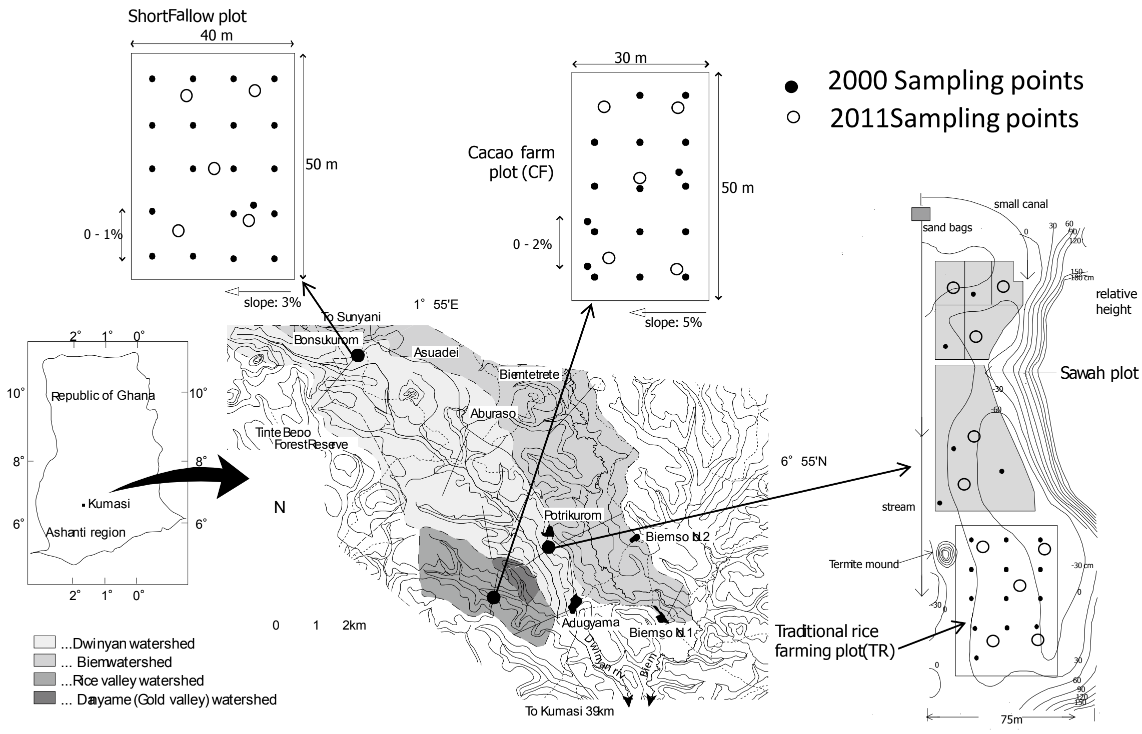

Fig. 1. showing the sampling location

Validation of analytical errors of two different periods

To ensure the reliability of the 2000 data, 27 soil samples sampled in 2000 were reanalysed using the same analytical methods and were compared with original data from Annan-Afful, et al., (2004) (Table 1). Table 1 shows the t-test analysis of the significant differences in 2000 and 2011 results as well as the correlation analysis. Significant difference in two period data mean there were errors that could not be ignored. Weak correlation of less than 0.46** mean that there were errors indicating difference between sample to sample. Based on the t-test and correlation analyses, we concluded that there were errors that could not be ignored in the analyses of Blay1-P, ex. Mg, K and Na, and avail. Fe and Mn. Therefore, we did not discuss these parameters on the change from 2000 to 2011. pH had weak correlation which was however due to little variation of data, hence we included pH in the discussions.

10.3. Results and Discussion

Soil property change during the period of 2000 - 2011

Fig. 2 shows the changes that occurred in soil fertility parameters between 2000 and 2011 across all the land use systems along the topo-sequence. Soil pH showed a non significant decline across all land use types except sawah with significant decline of -14.51% and -10.99% at 0-20cm and 40-60cm respectively and TR with a decline of -14.60% at depth of 40-60cm**.** The results revealed that a topsoil decline of -14.51%, -8.72%, -8.14% and -7.39% was observed in Sawah, TR, Fallow and CF respectively. The decline in pH cuts across the depth in all the land use system except 20-40 cm in Fallow. This decline in pH according to Ali et al. (1997) and Darmawan et al. (2006) is as a result of the depletion of exchangeable cations. Pierre et al. (1970) reported that the application of nitrogenous fertilizers led to a decrease in the pH in soils of West Africa. The addition of nitrogenous fertilizer such as urea and ammonium sulfate without the addition of lime which is a common practice in the study area also contributed greatly to the decrease in the pH especially in Sawah and TR. Although there are variations in the degree of the decrease in the pH, this decline in pH could also be due to leaching from high amounts of rainfall. Water passing through the soil leaches basic nutrients such as calcium and magnesium from the soil and are thereby replaced by acidic elements such as aluminum and iron leading to a decrease in pH.

TC showed a significant decline in topsoil TR and CF. There was also a significant decline in TN in Fallow (40-60cm), TR (0-20 cm and 20-40 cm) and CF (0-20 cm). There was no significant decline in TC and TN in Sawah. A decline of -14.32%, -16.32%, -32.80% and -49.08% in TC was observed in topsoil of Fallow, Sawah, CF and TR respectively. TC decline cuts across the depth of all the land use systems under investigation. TN also showed a similar decline of -14.17%, -13.51%, -33.12% and -47.68% for topsoil of fallow plot, sawah, CF and TR respectively and cut across the soil profile. This decline in TC and TN is also in agreement with Ali et al. (1997) who reported a decline in the content of TC and TN between 1967 and 1995 in Bangladesh. The decrease in the TC and TN could be as a result of accelerated decomposition of organic matter under tropical climatic conditions (Ali et al. 1997) observed in this study. Carbon and nutrient contents usually decline exponentially with long term low-input cultivation especially when forests are converted to agricultural lands (Solomon et al., 2007; An et al., 2008; Kinyangi, 2008). The decline in the content of TC and TN could also be related to limited addition of organic matter in the study sites as reported by Ali et al. (1997). The study concluded that Fallow land use could maintain TC and TN with natural vegetation recovery which resulted in the non significant decline in the content of TC and TN especially at topsoil.

Except at 20-40 cm depth in Fallow, there was no significant decline in ex. Ca across all land use types. A decrease in the content of ex. Ca except in subsoil of sawah plot (20-40 cm and 40-60 cm depth) and across the depth for fallow plot (0-20 cm, 20-40 cm and 40-60 cm) was observed. This variation could be related to the management practices employed. It could also be as a result of crop uptake and/or leaching associated with high rainfall in the study area. Generally, the decline of the exchangeable bases is as a result of the degradation of exchange complexes such as humus and clay as reported by Ali et al. (1997). The decline in exchangeable bases could also be due to depletion in organic matter as observed in the content of TC and TN across the land use systems. Organic matter enhances the retention of exchangeable bases (Ali et al., 1997).

Avail. Zn showed a decline trend in all the land use systems. There was a significant decline in Zn in all the land use types except in 40-60 cm depth of TR and CF. A previous study conducted by Buri et al. (2000) reported Zn as deficient in lowland soils of West Africa. The low level of Zn in West African soils coupled with plant uptake might be responsible for the decline in Zn content in the present study. Available Cu showed a decline trend in all land use systems during the period of 2000 and 2011. There was a significant decline in Cu in topsoil of Fallow. The decline of micronutrient across the land use systems is as a result of the nature of the parent materials of these soils and land use management adopted.

Although, fallow of between 2000 and 2011 is expected to improve in all major fertility parameter, unexpectedly, the reverse is the case in the study area. This unexpected result may be due to erosion. High rainfall erosivity due to generally intense tropical rains (Moore, 1979; Angima et al., 2003) and high soil erodibility make soils in the study area sensitive to depletion irrespective of whether it is on cropping or on fallow. According to

Mbagwu (1998), pH, organic matter content, total nitrogen, available phosphorus, exchangeable bases and cation exchange capacity are the most adversely affected soil chemical properties by erosion or topsoil removal in Sub-Saharan Africa (SSA). The decrease in the fallow plot may also be due to leaching as a result of the high rainfall recorded in the area. The parent materials of these soils may also account for the nature of decline observed. Long term intensive use without proper management practices, low inputs and poor management, intensive cultivation, uncontrolled burning of vegetation and deforestation also play a key role in the depletion of the soil. Depletion of soil fertility need apart from fallow other methods of conservation agriculture and proper soil fertility management planning for a sustainable production to replenish the loss of many years. Another factor which explaining the decline in the study area may be associated with weathering. As reported by Issaka et al (1996), soils of West Africa had undergone a severe weathering which accounts for the low content of major fertility parameters.

Despite the decline in all the land use types, it was observed that the degree of decline in sawah plot was relatively lower compared to other land use types especially TR. Sawah and TR are cultivated in lowland of the IV under same climatic and soil conditions. Sawah soil showed no significant decline in all the parameters under investigation except pH. Sawah system of rice production encouraged the growth of not only the rice but also various aquatic algae and other aerobic and anaerobic microbes which increase nitrogen fixation in the sawah system through increase of photosynthesis as multi-functional wetlands. There was no significant decline in TC and TN in across the depth. Organic matter content plays a vital role in soil fertility management. Sawah also received nutrients from upland through the process of geological fertilization. Nutrients from upper part of the IV are transported to the lower parts therefore enriching the fertility status of sawah plot. In addition, bunds constructed across sawah basins serve as barriers which reduce the rate of erosion, the major cause of degradation in the study area. Bunds constructed across sawah also ensure proper nutrient management which influence the results obtained in this study.

The decline in the soil properties between 2000 and 2011 showed a great potential for soil degradation in the study area. The result has also confirmed the reported decline in yields of most crops in last 10 years (Diao and Sarpong, 2007) and therefore calls for urgent attention in addressing the trend. Increasing production of staple crops through the development of the IVs may be a mirage if efforts are not made to address the rate of decline in soil fertility. With the decline in the fertility status of fallow plot, it is evident that subjecting the soils in the study area to fallow may not be enough to replenish the decline in the fertility status, but however, a combination of conservative agricultural practices should be adopted to ensure proper soil management and prevent further degradation of these soils. Sawah technology therefore remains the best alternative for developing the IV of the Ashanti region of Ghana as well as other regions of Ghana mostly affected by soil degradation. Sawah technology with soil improvement, water management and high yielding characteristics will remain the best strategy to increase and maintain rice production levels. According to Wakatsuki et al, (2011), lowland sawah systems can support rice cultivation continuously for decades, centuries or more without any fallow period.

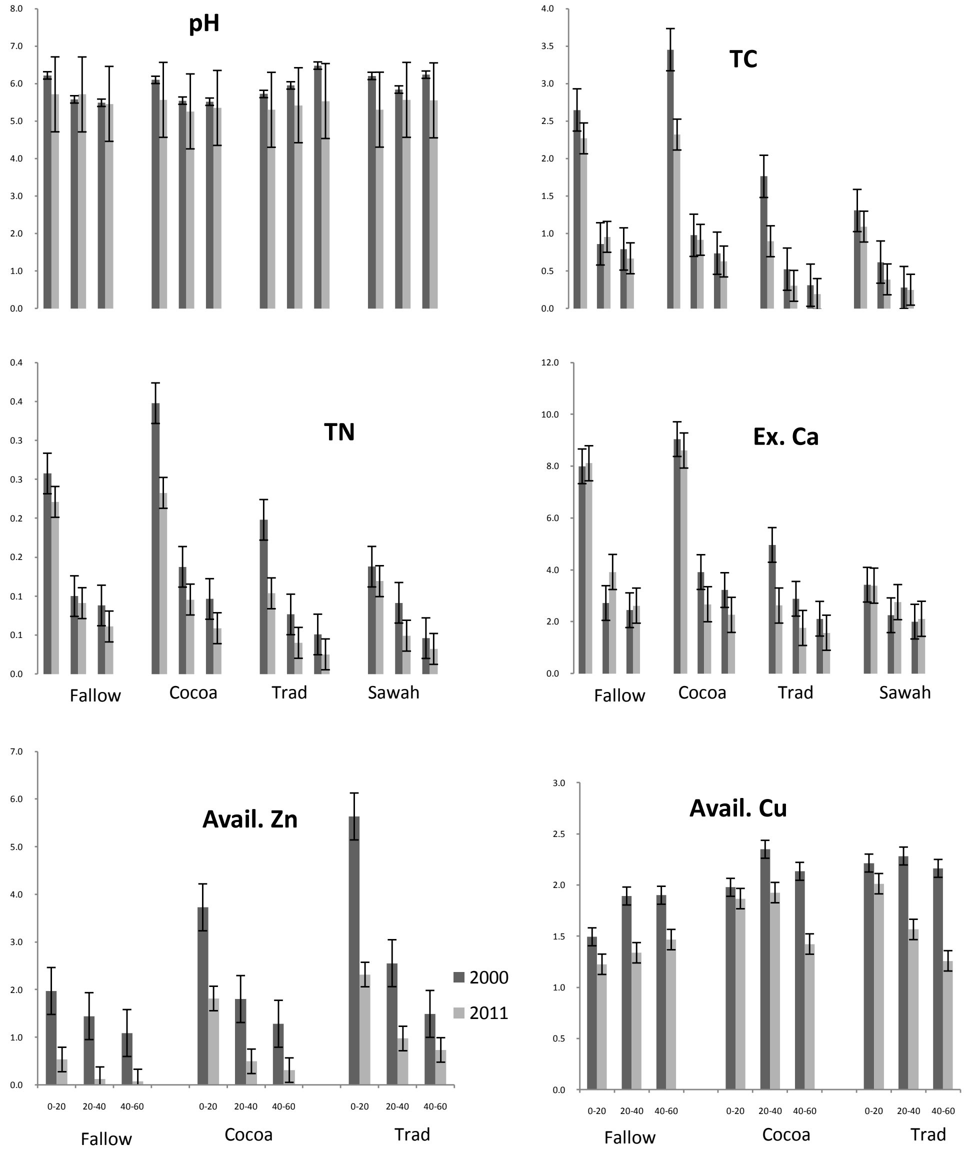

Fig. 2. Changes in Soil Fertility properties between 2000 and 2011

Table 1. Validation of analytical errors for comparing two different periods of analysis using the same sample sets.

		pH	Blay1-P	TC	TN	Ca	Mg	K	Na	Zn	Cu	Fe	Mn
						Exchangeable				Available			
		(H_2O)	(mg P kg^{-1})	(g kg^{-1})		(cmolc kg^{-1})				(mg kg-1)			
2000 A	Mean	5.6	3.72	0.94	0.12	2.93	1.49	0.21	0.22	3.26	2.19	137	24.5
		(4.95-6.27)	(0.73-13.5)	(0.17-3.53)	(0.02-0.38)	(1.1-6.72)	(0.69-3.02)	(0.07-0.63)	(0.11-0.58)	(0.44-12.34)	(0.69-5.37)	(22.78-357.18)	(3.79-59.32)
2000 B	Mean	5.4	5.67	0.81	0.09	2.60	1.12	0.17	0.15	2.52	1.73	96	38.4
		(5.07-5.99)	(0.87-22.17)	(0-3.27)	(0-0.39)	(1.10-7.26)	(0.58-2.64)	(0.08-0.67)	(0.07-0.48)	(0.22-13.29)	(0.52-3.49)	(13.76-335.73)	(5.55-157.03)
	B/A	0.98	1.52	0.87	0.77	0.89	0.75	0.78	0.67	0.77	0.79	0.70	1.57
	t-test	NS	**	NS	NS	NS	*	NS	*	NS	NS	*	*
	Correlation coefficient	0.03	0.99**	0.70**	0.64**	0.62**	0.36	0.26	0.17	0.90**	0.79**	0.85**	0.88**
Validation			x				x	x	x			x	x

A and B represents analytical result done in year 2000 and 2011 respectively using same sample sets.

Figures in parenthesis represent the range

Table 2a: Changes in Soil fertility parameters between 2000 and 2011 in Fallow

Year	Land Use	Depth	Statistics	pH (H_2O)	TC (g kg^{-1})	TN (g kg^{-1})	CN	Exch. Ca (cmolc kg^{-1})	Available Micronutrients: Zn (mg kg-1)	Available Micronutrients: Cu (mg kg-1)
2000	Fallow	0-20	Mean	6.22	2.65	0.26	10.25	7.99	1.97	1.49
			SD	0.13	0.13	0.01	0.17	1.16	1.67	1.26
2011	Fallow	0-20	Mean	5.71	2.27	0.22	10.17	8.11	0.53	1.23
			SD	0.20	2.83	0.22	0.32	1.74	0.13	0.12
% Change				-8.14	-14.32	-14.17	-0.80	1.48	-72.93	-17.98
t-test				1.88	1.345	1.626	0.227	-0.049	3.457	2.024
				NS	NS	NS	NS	NS	**	NS
2000	Fallow	20-40	Mean	5.58	0.86	0.10	8.71	2.72	1.44	1.89
			SD	0.16	0.04	0.00	0.28	0.73	1.24	1.60
2011	Fallow	20-40	Mean	5.71	0.96	0.09	10.52	3.92	0.12	1.34
			SD	0.33	0.55	0.05	0.35	0.75	0.03	0.18
% Change				2.37	10.93	-9.00	20.78	44.15	-91.67	-29.31
t-test				-0.387	-1.126	0.96	-3.176	-3.116	2.829	3.189
				NS	NS	NS	**	**	*	**
2000	Fallow	40-60	Mean	5.49	0.80	0.09	9.09	2.44	1.09	1.90
			SD	0.15	0.03	0.00	0.21	0.79	0.93	1.60
2011	Fallow	40-60	Mean	5.46	0.67	0.06	11.00	2.62	0.07	1.47
			SD	0.32	0.20	0.02	0.31	0.43	0.02	0.19
% Change				-0.55	-15.67	-30.68	21.07	7.24	-93.43	-22.81
t-test				0.092	2.024	3.833	-4.543	-0.115	2.848	2.422
				NS	NS	**	**	NS	*	*

Table 2b: Changes in Soil fertility parameters between 2000 and 2011 in Sawah

Year	Land Use	Depth	Statistics	pH (H_2O)	TC (g kg^{-1})	TN (g kg^{-1})	CN	Exch. Ca (cmolc kg^{-1})	Available Micronutrients Zn (mg kg-1)	Available Micronutrients Cu (mg kg-1)
2000	Sawah	0-20	Mean	6.21	1.31	0.14	9.48	3.43	NA	NA
			SD	0.11	0.10	0.01	0.17	0.28		
2011	Sawah	0-20	Mean	5.31	1.09	0.12	9.17	3.39	4.54	2.63
			SD	0.23	2.39	0.26	0.22	1.24	1.91	0.82
% Change				-14.51	-16.41	-13.51	-3.22	-1.10		
t-test				3.127	0.849	0.709	0.714	0.051		
				**	NS	NS	NS	NS		
2000	Sawah	20-40	Mean	5.84	0.62	0.09	6.68	2.25	NA	NA
			SD	0.16	0.10	0.01	0.38	0.41		
2011	Sawah	20-40	Mean	5.57	0.39	0.05	7.90	2.75	1.56	2.09
			SD	0.26	0.84	0.11	0.04	0.42	0.55	0.69
% Change				-4.70	-37.23	-46.19	18.39	22.52		
t-test				1.307	1.686	2.557	-2.652	-0.842		
				NS	NS	NS	*	NS		
2000	Sawah	40-60	Mean	6.24	0.28	0.05	5.89	2.00	NA	NA
			SD	0.14	0.08	0.01	0.29	0.57		
2011	Sawah	40-60	Mean	5.55	0.25	0.03	7.74	2.11	1.14	1.57
			SD	0.14	0.47	0.06	0.17	0.27	0.32	0.44
% Change				-10.99	-10.21	-30.00	31.48	5.47		

t-test	3.401	0.307	1.064	-5.546	-0.174
	**	NS	NS	**	NS

Table 2c: Changes in Soil fertility parameters between 2000 and 2011 in Traditional Rice

									Available Micronutrients	
				pH	TC	TN	CN	Exch. Ca	Zn	Cu
Year	Land Use	Depth	Statistics	(H_2O)	(g kg^{-1})			(cmolc kg^{-1})	(mg kg-1)	
2000	TradRice	0-20	Mean	5.73	1.76	0.20	8.80	4.96	5.63	2.21
			SD	0.13	0.15	0.02	0.23	0.58	1.13	0.40
2011	TradRice	0-20	Mean	5.30	0.90	0.10	8.65	2.62	2.32	2.01
			SD	0.14	0.56	0.05	0.16	0.33	0.35	0.23
% Change				-7.39	-49.08	-47.68	-1.76	-47.17	-58.89	-9.11
t-test				1.527	2.755	2.962	0.33	1.97	2.131	0.352
				NS	*	**	NS	NS	*	NS
2000	TradRice	20-40	Mean	5.95	0.53	0.08	7.02	2.88	2.55	2.28
			SD	0.15	0.06	0.01	0.37	0.47	0.47	0.43
2011	TradRice	20-40	Mean	5.42	0.30	0.04	7.59	1.76	0.97	1.57
			SD	0.14	0.34	0.05	0.14	0.11	0.17	0.28
% Change				-8.88	-42.30	-47.71	8.21	-39.05	-61.88	-31.43
t-test				1.688	1.963	2.4	-0.765	1.181	2.431	1.149
				NS	NS	*	NS	NS	*	NS
2000	TradRice	40-60	Mean	6.48	0.31	0.05	6.32	2.11	1.49	2.16
			SD	0.21	0.05	0.01	0.41	0.44	0.67	1.08
2011	TradRice	40-60	Mean	5.54	0.19	0.03	7.67	1.57	0.73	1.26

			SD	0.09	0.17	0.02	0.15	0.10	0.16	0.27
% Change				-14.60	-37.79	-50.36	21.40	-25.64	-50.75	-41.79
t-test				2.689	1.394	1.986	-1.974	0.753	1.224	0.904
				*	NS	NS	NS	NS	NS	NS

Table 2d:Changes in Soil fertility parameters between 2000 and 2011 in Traditional Cocoa plot

Year	Land Use	Depth	Statistics	pH (H_2O)	TC ($g\ kg^{-1}$)	TN	CN	Exch. Ca ($cmolc\ kg^{-1}$)	Available Micronutrients: Zn (mg kg-1)	Cu
2000	Cocoa	0-20	Mean	6.10	3.45	0.35	10.11	9.04	3.73	1.98
			SD	0.17	0.16	0.02	0.40	1.33	0.34	0.15
2011	Cocoa	0-20	Mean	5.57	2.32	0.23	9.96	8.60	1.81	1.87
			SD	0.10	3.05	0.29	0.19	1.21	0.31	0.47
% Change				-8.72	-32.80	-33.12	-1.48	-4.86	-51.33	-5.56
t-test				1.589	3.323	3.095	0.194	0.167	3.09	0.297
				NS	**	**	NS	NS	*	NS
2000	Cocoa	20-40	Mean	5.55	0.98	0.14	8.23	3.91	1.80	2.35
			SD	0.16	0.06	0.02	0.60	0.44	0.25	0.24
2011	Cocoa	20-40	Mean	5.26	0.92	0.10	9.89	2.67	0.49	1.93
			SD	0.15	1.52	0.19	0.44	0.85	0.18	0.56
% Change				-5.17	-6.13	-30.55	20.17	-31.73	-72.56	-18.02
t-test				0.921	0.421	1.105	-1.446	1.328	3.029	0.818
				Ns	NS	NS	NS	NS	**	NS
2000	Cocoa	40-60	Mean	5.52	0.74	0.10	8.92	3.22	1.28	2.13

			SD	0.22	0.07	0.02	0.79	0.65	0.18	0.38
2011	Cocoa	40-60	Mean	5.35	0.63	0.06	11.06	2.26	0.31	1.42
			SD	0.16	1.13	0.13	0.47	0.68	0.09	0.39
% Change				-3.01	-14.95	-38.98	24.00	-29.71	-75.86	-33.30
t-test				0.477	0.853	1.289	-1.739	0.893	1.696	1.655
				NS	NS	NS	NS	NS	NS	NS

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CHAPTER 11

Summary

This study examined the socio-economic factors and soil fertility status affecting the adoption and dissemination of sawah technology in Nigeria. This study further evaluated the factors responsible for the adoption of sawah technology in Ghana and the degree of soil property changes in Ghana with a decade of adoption of sawah technology.

The study revealed that high yield from sawah, good tillering, water management, fertilizer management and weed control and other characteristics of sawah technology were the major reasons why farmers adopted sawah technology. Adoption of sawah technology was influenced positively by awareness, attitude of farmers, attributes of sawah technology, access to contact farmers and household size and negatively influenced by age of farmers and the constraints faced by farmers.

Study on land tenure brought to the fore the fact that land tenure arrangements significantly affect the adoption of sawah technology by farmers in Nigeria. Security of land determined the level of adoption of sawah technology among the farmers. Ensuring high levels of tenure security is important for sustainable adoption of sawah technology**.** Success of sawah technology adoption based on the findings of this study centres on land availability to the farmers with long-term security. The likelihood for farmers to make medium to long-term land improvement investments tends to be high if their tenure is secured, they will be more likely to benefit from whatever investment they might go into. The study also revealed that

access and control over use of land varied among land owners and tenants which invariably influence their adoption of sawah technology. Control over the land rests solely with the landlords. Landlords decide the size of the land to be cultivated by tenants and may prevent tenants from expanding the size of their sawah farms. Transfer rights related to the land also rest solely with the landlords, allowing them to rent it out, share its usage, leave it fallow, bequeath it, or sell it. Land tenants have only the right to use the land, and restrictions are imposed by landlords.

Major constraints to adoption of sawah technology were identified. The constraints, covering a wide array of issues included land acquisition and tenure, economic, information, communication and training, technical and mechanical constraints. The most severe constraints related to land acquisition and tenure were poor fertility of the soil, poor road network from their farms to city centre, and rough topography of the farm need to be leveled , which results in high cost for adoption of sawah technology and rice cultivation. Economic constraints faced by sawah farmers are lack of viable financial agencies to support their production, poor capital base for farming and non-availability of loan to support farming. Technical and mechanical constraints confronted by sawah farmers include non availability of power tillers for land preparation activities, lack of skill for land and site selection, and complexity of water management.

The areas of priority for training among the farmers are water management, power tiller operation and management, and sawah plot layout. Farmers are willing to attend on-the-job training if given the opportunity. Technical areas of sawah technology such as sawah layout and design, site selection for sawah rice production, power tiller operation and management are the areas of training needs of extension agents. In addition, attention should also be given to improvement of the professional competencies of extension agents in the areas such as conducting demonstrations, farmers training and communication skill for effective dissemination of sawah technology.

The study on the fertility status of sawah soil in Nigeria found that sawah soils in Nigeria are low in major soil fertility parameters. The study revealed that sawah soils in Nigeria are predominantly sand. The study further revealed that sawah soils are acidic and lacking in basic fertility parameters such as exchangeable bases, TC, TN, avail. S avail. P and avail. SiO_2. The results further showed that sawah soils in Nigeria are deficient in avail. Zn, moderate in avail. Cu, Ni and Mn. Available Fe was found to be moderate with minor avail. Fe toxicity. The results of total elemental analysis showed that sawah soils in Nigeria exhibited intermediated to extreme weathering rate with majority of the soil sampled falling into the category of extreme weathering rate.

Experience from Ghana revealed that sawah technology adoption was influenced by age, education in addition to year of experience in rice production, contact with extension agents and attendance in previous trainings, land tenure arrangements and yield. The study also showed a decline in soil fertility of farm lands during a decade of sawah development in Ghana with a great potential for soil degradation. Despite the significant decline of TC and TN contents by 30 to 40% in traditional rice field or cacao plantation, it was observed that those in sawah plot were kept in the same level as well as fallow land use did. This indicates soil fertility could be maintained by sawah technology adoption, which contributes to the achievement of sustainable rice production in this region.

Land Tenure System and Soil Fertility Status for Adoption of Sawah Technology in Nigeria and Ghana

ナイジェリアとガーナにおける Sawah 技術採用のための、土地保有制と土壌肥沃度状態に関する研究

要旨

本研究では、ナイジェリアにおけるsawah技術の採用と普及に影響を与える社会—経済的要因および土壌肥沃度状態について調べた。さらに、ガーナにおけるsawah技術の採用に深く関わる要因と、sawah技術採用後10年間の土壌特性の変化について評価した。

本研究により、農民がsawah技術を採用した理由は、高収量、良好な分けつ-水管理-肥料管理-雑草制御、その他のsawah技術の特性であることが明らかとなった。sawah技術の採用は、技術の認知（awareness）,農民の姿勢（attitude of farmers）, sawah技術の特質（attributes of sawah technology）, 技術を知る農民との交流（access to contact farmers）、家庭の大きさが正の影響を及ぼし、農民の年齢と農民が直面する様々な制約（the constraints faced by farmers）が負の影響を及ぼしていた。

土地保有に関する研究は、土地保有に関わる約束事が、ナイジェリアにおけるsawah技術の採用に大きく影響していることを明らかにした。土地保有の保障（土地所有者と土地を借りる農民の間の約束が守られ，農民が安心して土地を使うことができ

るかどうかの保障、security of land）がsawah技術採用の程度を決定していた。確実な土地保有（利用権利）の保障が、適切なsawah技術の採用に重要であった。sawah技術の採用が成功するには、農民が長期間土地を保有できる事がカギとなる。農民の土地保有が保障された場合、農民は投資に見合う利益を見込めるため、中-長期の土地改良投資する見込みが高くなる。土地へのアクセスや土地利用方針が土地所有者や借地人で異なることは、sawah技術の採用に対して異なる影響を与えていることが明らかとなった。土地利用に関する規制は、土地所有者（小作人の主人）が単独で決めている。土地所有者が小作農の耕作面積を決めており、sawah農民が耕地を拡大する事を妨げることがある。土地に関する権利（貸し出し、共有、休閑、遺贈、売却）の移管についても土地所有者にかかっている。借地人は土地を利用する権利だけしか有せず、土地所有者に様々な規制を押しつけられている。

sawah技術の採用に対する主な制約は、土地の入手や保有（利用権利）状況、農民の経済状況、技術に関する情報、農民間の情報と技術交流、農業技術と機械の不足であった。土地の入手と保有に関する最も厳しい制約は、獲得できる土地が貧栄養であること、農地から街の中心までの道が無い事、凸凹の地形で均平化が必要な事、にコストがかかることであった。農民が直面している経済的な制約は、彼らの農業を支える金融機関が無い事である。農業技術と機械に関する制約は、土地整備のための耕耘機が無い事、適地判定技術を持たないこと、および水管理の複雑さである。

農民が優先して受けるべきトレーニングは、水管理、耕耘機の運転・維持管理、sawah区画配置の方法であり、農民は機会があればon-the-job trainingに参加したいと

考えている。Sawah区画の配置やデザイン、適地判定、耕耘機の運転・維持管理には普及員によるトレーニングが必要な分野である。そして、sawah技術の効率的な普及には、デモンストレーション実施、農民の研修、コミュニケーションなどの分野について普及員の能力改善に注意を払うべきである。

ナイジェリアのsawah土壌の主要な特性因子の肥沃度は低かった。土壌は砂質、酸性であり、交換性塩基、全炭素、全窒素、可給態S、可給態P、可給態SiO_2の含有量は低かった。さらに、可給態Znは欠乏しており、可給態Cu, Ni, Mn含有量は中程度であった。可給態Fe含有量は、一部の地域で過剰レベルであったが、ほとんどの地域で中程度であった。全量分析の結果、土壌の風化程度は中程度から強度の風化状態であり、ほとんどの土壌が強度の風化状態であった。

ガーナにおいて、sawah技術の採用は農民の年齢、稲作の経験年数に加えて教育レベル、普及員との接触、sawah技術普及トレーニングへの参加、土地保有の状況、収量であった。ガーナにおけるsawah普及が進んだこの10年間で農地土壌の肥沃度低下が見られた。伝統的な稲作地およびカカオ畑では全炭素、全窒素が30-40%減少したにもかかわらず、sawah区画では休閑地と同様に全炭素、全窒素レベルが維持されていた。この事は、sawah技術の採用により土壌肥沃度が維持され、この地域の持続的なコメ生産に寄与することを示唆している。

APPENDIX 1

SURVEY INSTRUMENT.

Section 1
The effect of land tenure system on sawah eco-technology development and sustainability among rice farmers in selected states in Nigeria

Dear Respondent,

This study is designed to investigate The Effect of Land Tenure System on Sawah Eco-Technology Development and Sustainability among Rice Farmers in Selected States in Nigeria
Your honest and forthright response to this questionnaire will be highly appreciated. Assurance is being given that information supplied will be used strictly for academic and research purposes.
Thank you very much for your time.
ALARIMA C. I.

A. **PERSONAL INFORMATION/DEMOGRAPHIC CHARACTERISTICS OF RESPONDENT**

- Name of Respondent: ....
- State ....
- Local Government ....
- Community/village ....
- Sex: Male Female
- Age in years:..
- Marital status: (a) Married (b) single
- Years of settlement:
- Ethnicity:
- Educational level: No formal education=1 Primary = 2 secondary School = 3 Tertiary = 4
- Household size: .... Males .... Females ....

- Number of Children in household: .... Males .... Females
- Farm size in hectares...
- Income per month .... in Naira
- How many years have you been growing rice? ....
- What are the yields of your non Sawah farm? ....
- How many years have you practised Sawah rice farming? ....
- What are the yields of your Sawah farm? ....
- Sawah Farm size in hectares...
- Land type: (a) upland (b) Fringe (c) lowland (d) others
- Sawah type: a) bunding (b) bunding and puddling (c)) bunding and puddling and leveling (d) high quality sawah (d) Non sawah
- Soil Sample...
- Waypoint coordinate ....
- Distance from respondent's house .... in km

B. ACCESS TO LAND FOR RICE PRODUCTION
Rice Farmers please tick all the ones that apply to your situation

- How do you gain access to land in this community?
  Own = 1 Communal Rights = 2 Sharecropping = 3 Rentals = 4
  Allocation by family head = 5 Allocation by Chief = 6
  Allocation by Government = 7 (8) Pledge (9) Purchase (10) Inheritance (11) Gift (12) Borrow Others = 8 (State)

- Who has access to land in the community?
  Native = 1 Settler = 2 Both Natives & Settlers = 3 Migrating farmers = 4

- Do natives and settlers have equal access? Yes = 1 No = 2 Can't tell = 3
- If no
  why? ....
  ....
  ....
- Are the methods of accessing wetland for rice production different from upland crops?
  Yes = 1 No = 2

  If yes, what are the differences?
  ....
  ....
  ....
- Do farmers from your community migrate to other communities to access wetlands for rice production? Yes = 1 No = 2 Can't tell = 3
- If yes, why?
  (a) No access to land in the community (b) small wetland available (c) poor working atmosphere

- Do farmers from other communities migrate into your community to access wetlands for rice production? Yes = 1 No = 2 Can't tell = 3
- If yes why?
  (a)No access to land in the community (b) small wetland available (c) poor working atmosphere

ACQUIRING LAND FOR RICE PRODUCTION

- Which of the following influences land acquisition in your community?

Social relations = 1 Social Status = 2 Financial factors = 3 Ethnicity = 4
Other factors = 5 (Specify)

- By which of the following methods did you acquire your land for rice production?
  Own = 1 Maternal inheritance = 2 Paternal inheritance = 3
  Rentals = 4 Communal Rights = 5 Sharecropping = 6
  Gift = 7 Allocation by Chief = 8 Allocation by family head = 9
  Allocation by Government = 10 Purchase = 11 others = 12 (State)
- If own land, how did you come by it? Lump sum purchase = 1
  Inheritance = Gift = 3 Others = 4 (specify)

- If share cropping, indicate percentage of produce paid as rent:
  >70% = 1 50-69% = 2 <50%

- If Communal Rights
  What are the conditions for holding Communal Rights?
  (a)By birth (b) by Marriage (c) by Registration

- At the communal level who has control?
  (a)king/queen (b) chiefs (c) age grade associations (d) Oba in council

  If Allocation is by Family Head
- Who heads the family? Male = 1 Female = 2
- If female headed-family indicate it? Single = 1 Married = 2 Widowed = 3
  Migrant husband = 4 Aged/Infirm husband? = 5
- Under what conditions does a family head allocate wet lands for rice production?
  ....
  ....
  ....

  If Allocation by the Chief
- Under what circumstances does the chief allocate wetlands for rice production?

  If Allocation by the Government (State)
- What are the conditions for benefiting from an allocation by the Government?
  ....
  ....
  ....

  If Leasehold Contract
- If Leasehold Contract please indicate terms of contract:
  Temporary = 1 Number of
  years: ....

Long Term = 2 Number of years: ....

- **If purchased**
  From whom did you buy the land? (a)Family (b) Individuals (c)Agent (d) Government (e) community (f) others

  Kindly indicate the procedures you follow in purchasing land for the following purposes:

Procedures	**Rice production**	**Other Agric production**	**House**	**Other uses**
Inspection				
Payment				
Making agreement				
Survey				
Land registration				

Cost of purchasing land

Cost Breakdown	**Amount in Naira**
Deposit	
Broker	
Negotiation	
Real price	
Toposurvey	
Registration	
Tax	
Others specify	

What procedures do you employ to confirm the purchase of Land? (a) land registration
(b) traditional (c) Others

If Others

- What are the other ways of accessing land in the community?
  ....
  ....
  ....
- What interests do you hold in your land?
  Individual interest = 1 Family interest (Extended) = 2 Family interest (Nuclear) = 3
  Communal interest = 4 Others = 5 (Specify) ....

- What rights do you have to your land?
  Right of use = 1 Right of control = 2 Right of transfer = 3
- Are your rights secured? Yes = 1 No = 2

- If yes, how? ....

....

- If no, why? ....
....

- Do you have the ability to give a parcel of your land to someone as a gift?

  Yes = 1 No = 2

- If no, why? ....
....

- Can the land be taken over from you? Yes = 1 No = 2

- If yes by whom, indicate? Family head = 1 Chief = 2 Community head = 3 Others = 4 (Specify): ....

- Can you take land use decisions without any hindrance? Yes = 1 No = 2
- If no who takes land use decisions?
  Self = 1 Self in consultation with family = 2 Family head = 3
  Family head in consultation with family = 4 Can't tell = 5
- Does marriage affect your right of use? Yes = 1 No = 2
- If yes how? ....
....
....
- Does marriage affect your right of transfer? Yes = 1 No = 2
- If yes, how? ....
....
....
....
- What restrictions do you have to the use of your land?
....

C RENTALS

If your answer to question 36 was Rentals, answer questions 65-77

- What rights have you acquired?
  Right of use = 1 Right of control = 2 Right of transfer = 3
- Are your rights secured? Yes = 1 No = 2
- If yes, how? ....
....

- If no, why? ....
- If you have right of transfer, under what circumstances will this be done? ....
- What are the conditions of rent?
  Payment in kind, milled rice/paddy = 1   Payment by cash = 2   labour = 3 others =4 (Specify)
  ....
- What quantity (in %) of paddy/milled rice is paid as rent per acre (hectare)? ....
- How much cash is paid as rent per/acre ₦...
- Is the rent fixed in advance?   Yes = 1   No = 2 Others = 3 (Specify) ....
- What is the duration of tenancy? ....
- Are the terms of rent fair to you?   Yes = 1   No = 2
- If yes, how? ....
- If no, give reasons ....

D Nature of Tenancy Agreement

- What tenancy agreement have you contracted?
  Verbal = 1   Written = 2   No Agreement = 3   Other = 3 (Specify)
- Is the agreement a fixed rent tenancy?   Yes = 1   No = 2   Other = 3 (Specify)
- Do natives and settle have the same agreement conditions?
  Yes = 1   No = 2   Can't tell =3
- If no, why ....

....
....
....
....

- List the major problems you face with Tenancy Agreement
....
....
....
....
....
....
....

- List the other minor problems you face with Tenancy Agreement
....
....
....
....

E GENDER

In questions, 83, 84, 85 & 86 indicate who has access to resources & control over their use.

Tick separately for adults; women and men and for the youth; girls and boys.

- **Access and Control Profile**

	Women							
	Access							
	Full	Partial	Little	No	Ful l	Partia l	Littl e	No
A. Resources - Land - Equipment/Tools - Labour - Family labour - Hired labour - Improved Seed - Cash - Information - (Extension, Research, NGOs)								
B. Benefits								

- Income Cash - Income in-kind - Ownership								

- **Access and Control Profile**

	Men							
	Access							
	Full	Partial	Little	No	Full	Partial	Little	No
A. Resources - Land - Equipment/Tools - Labour - Family labour - Hired labour - Improved Seed - Cash - Information - (Extension, Research, NGOs)								
B. Benefits - Income Cash - Income in-kind - Ownership								

- **Access and Control Profile**

	Girls							
	Access							
	Full	Partial	Little	No	Full	Partial	Little	No
A. Resources - Land - Equipment/Tools - Labour - Family labour - Hired labour - Improved Seed - Cash - Information - (Extension, Research, NGOs)								
B. Benefits - Income Cash								

- Income in-kind - Ownership								

- **Access and Control Profile**

	Boys							
	Access							
	Full	Partial	Little	No	Ful l	Partia l	Littl e	No
A. Resources - Land - Equipment/Too ls - Labour - Family labour - Hired labour - Improved Seed - Cash - Information - (Extension, Research, NGOs)								
B. Benefits - Income Cash - Income in-kind - Ownership								

F. LANDOWNERS
Customary Land Systems, Landowner and Tenant Relationships
Please Land owner answer questions 87 to 104 Tick all the ones applicable

- What are the customary land tenure systems in this community?
  Own land = 1 Family Land = 2 Stool and sub-stool land = 3
  Government Land (State) = 4 Others = 5
  (Specify) ....
  ....
- Who has control over land?
  Individuals = 1 Families = 2 Stools and sub stools = 3
  Community head = 4 Government (state) = 5 Others = 6 (Specify)
  ....
- Do women have the same customary rights to land as men in the community?
  Yes = 1 No = 2
- If no,
  why? ....

....
....

- Which is important to you? Upland = 1 Wetland = 2 Both = 3 Can tell = 4
- What is your perceived importance of the wetlands?
  Very important = 5 Important = 5 Some what important = 3
  Little importance = 2 Not important = 1

Statement	**5**	**4**	**3**	**2**	**1**
Wetland give higher yield					
Wetland is easier to work on					
Wetland makes farming more interesting					
Wetland conserves soil fertility					
Wetland is easy to manage in term of weed control					
Wetland looks more attractive					
Wetland is cheap to acquire					
There is less conflict on wetland					

- Are you willing to release your land for sawah activities? Yes = 1 No = 2

- If no, why?
  ....
  ....
  ....
- How many years are you willing to release your wetland for sawah activities?.........................
- What is the procedure for acquiring wetlands for sawah rice production?
  ....
  ....
  ....
- What conditions can cause you to take over your land from a tenant sawah farmer?
  Refusal to pay rent = 1 Subletting = 2
  Failure to renew Tenancy agreement = 3
  Subvervance of the customary free holder's interest = 4
  Non observance of local customs and laws = 5
  Social abuse in the community = 6
  Others = 7
  (Specify)...
  ....
  ....

- Are farm lands sold out right in the community? Yes = 1 No = 2 Can't tell = 3
- If yes, who has the right to sell land?

....
....
....

- Will you want to sell your wetland out right to a sawah farmer Yes = 1 No = 2
- If yes, why?
  Wetlands are not important = 1 Financial crisis = 2 Litigation = 3
  Family Pressure = 4 Others = 5 (Specify):
  ....
  ....
  ....
- If no,
  why? ....
  ....
  ....
  ....
- What practical suggestions can you offer for improvement of landowner/tenant relationships? ....
  ....
  ....
  ....
  ....

G. SAWAH FARMERS

If you are a practicing sawah farmer, please answer questions 104 – 129

- What are the methods of rice cultivation practiced in your community?
  Upland = 1 Lowland = 2 Sawah = 3
- Do you have access to wetland in the community Yes = 1 No = 2
- If yes, is your interest in the land secured? Yes = 1 No = 2
- If no,
  why? ....
  ....
  ....
- What is the size of your sawah farm? ....

100. How many years have you been practising sawah farming? ....

101. How far is it from the community? ....

102. What is the paddy yield per acre?...

103. How did you acquire the land you are currently using?
Own = 1 Maternal inheritance = 2 Paternal inheritance = 3
Rentals = 4 Communal Rights = 5 Sharecropping = 6
Gift = 7 Allocation by Chief = 8 Allocation by family head = 9
Allocation by Government = 10 Others = 11 (State)

104. If Rentals , How long is the duration of your tenancy? ....

105. As sawah farmer, what incentive do you derive from the land?
....
....
....
106. How many years have you practised Sawah rice farming? ....
107. Have you had any conflict on your land? Yes = 1 No = 2
108. If yes, what was it about? ....
....
....
....
....
109. What are the risks involved in sawah rice farming?
....
....
....
110. What are the factors that can affect your long term land use of sawah?
....
....
....
111. In your own opinion what will hinder other farmers from investing in sawah?
....
....
112. Is land tenure a problem to you as a sawah rice farmer? Yes = 1 No = 2
113. If yes, tick the predominant problems? Multiple response allowed

Severity of the constraints

Constraints	Very severe	Severe	Not severe
Accessibility			
Availability			
Dispute and conflict			
Tenancy payment			
Longevity of use			
Interference			
Government policies			
Acquisition			

114. List the other minor land tenure problems you have?
....
....
....
....
115. What practical suggestions can you offer for improvement of sawah tenant/landowner

relationships? ....
....
....
....
....
116. What type of inheritance is practiced in this community? Matrilineal = 1 Patrilineal = 2
117. How can each affect sawah development and its sustainability positively or negatively?

Matrilineal: ....
....
....
....

Patrilineal: ....
.....
....
118. Suggest practical ways for the sustainability of sawah eco-technology?
....
....
....

H. Agricultural Constraints other than Land Tenure inhibiting production

119. Do you have constraints other than Land Tenure inhibiting production?
Yes = 1 No = 2

120. **Identification of major constraints to sawah rice production**

Constraint	Yes	No
Small farm size		
Lack of co-operation among farmers		
Negative attitude towards sawah		
High capital cost of improved farm implements/ machinery		
Mechanization and machinery		
High cost of operation		
Non-availability of suitable Implements		
Non-availability of spare parts		
Inadequate service and repair facilities		
High mechanical complexity of improved machinery		
Lack of credit facilities		
Low profitability of rice cultivation		
Plentiful availability of human		

labourers		
Cheap labour availability		
Opposition from farm labourers		
Lack of skilled labourers for operating improved machinery		
Lack of awareness		
Lack of knowledge of sawah technology		
Flood		
Drought		

122. Are the problem of Sawah rice farmers different from other food crops?
Yes = 1 No = 2

123. If yes give reasons
....
....
....

124. Suggest possible solutions to these problems?
....
....
....
....

125. What are your coping strategies to the constraints?
....
....
....

126. Right of respondents on their land.

Kindly indicate the types of right you have over the land you are using:

Right of respondents	**Yes**	**No**
Right to choose one's type of farming		
Right to leave the land fallow		
Right to develop the land		
Right to gather firewood for family consumption		
Right to gather wild fruits for family consumption		
Right to fell trees for sale		
Right to graze owned livestock		
Right to prevent livestock grazing from other owners		
Right to collect the entire yield without paying rent		
Right to loan out one's land		
Right to give out one's land		
Right to bequeath one's land		
Right to hire out one's land		

127. Nature of land conflict in the study area.

Have you had any conflict of any kind since you started sawah?

Yes = 1   No = 2

Kindly indicate the nature of conflict in your farm location

Nature of conflict		
Inter ethnic		
Intra ethnic		
Inter community		
Intra community		
International		
Stakeholder in the conflict		
Religious		
Political		
Resource control		
Actors of conflict		
Settlers (non- authochonous group)		
The State		
Root /Location of conflict		
Urban		
Rural		

128. What are the Causes of conflict faced by you? (Multiple response allowed)

(a)Scarcity (b) Group identity (c) Relative deprivation (d) Poverty- socioeconomic causes
(e) Institutional change e.g. political causes (f) Change in society, demography and ecology
(g) Corruption (h) lack of demarcation

At what point did conflict normally start in your community

(a) Beginning of cropping season (b) during the growing season (c) at harvest

How often do you have the conflict?

(b) Only at first planting season (b)every planting season (c) not at all

129. Conflict resolution methods

How do you resolve your land conflicts when they occur?

Effectiveness of the Conflict resolution methods

Methods	**Yes**	**No**	**Very effective**	**Somewhat effective**	**Not effective**
Courts/litigation					
Land administrators					
Police					
Politicians					
Kinship					
Religious leaders					
social networks					
Mediators					
Consultation					

Section 2

Factors affecting adoption of sawah eco-technology in Nigeria.

1. Awareness and Adoption of sawah ecotechnology package

Innovation package	Awareness	Adoption
Puddling		
Flooding		
Levelling		
Smoothnening		
Nursery		
Power tiller use		
Dyke construction		
Bond construction		
Agroforestry and sawah production		
Cannal construction		
Use of sand bags		

2. Level of adoption of sawah ecotechnology package

Innovation package	Full Adoption	Partial Adoption	Discontinued
Puddlin g			
Flooding			
Levelling			
Smoothnening			
Nursery			
Power tiller use			
Dyke construction			
Bond construction			
Agroforestry and sawah production			

Cannal construction			
Use of sand bags			

3. Reasons for the adoption of sawah ecotechnology rice production

Reasons	Yes	No
High yield		
Disease management		
Pest management		
Fertilizer management		
Weed control		
Water management		
Land preparation		
Good tillering		

4. Factors affecting the adoption of sawah ecotechnology rice production

Factors	Yes	No
Access to credit		
Access to extension		
Access to market		
Availability of input		
Internal and External Communication		
Opinion Leaders and Change Agents		
Technical Knowledge Resources		
Attitude towards Change		
Infrastructural		
on-farm field trials		
perceived usefulness,		
perceived ease of use		
Religious values		
Relative Advantage-Is it better you former method?		
CompatibilityIs -it appropriate for your adoption?		
ComplexityIs- it understandable to your		
TrialabilityCan- is it testable?		
Observability-What does it look like to you		
Communication factor		
Fear and anxiety		
Perceived risk and uncertainty		

5. Identification of major constraints to sawah rice production

Constraint	Yes	No
Small farm size		
Lack of co-operation among farmers		
Negative attitude towards		
High capital cost of improved farm		

implements/ machinery		
Mechanization		
High cost of operation		
Non-availability of suitable Implements		
Non-availability of spare parts		
Inadequate service and repair Facilities		
High mechanical complexity of improved machinery		
Low custom hire facilities		
Lack of credit facilities		
Low profitability of rice cultivation		
Plentiful availability of human Labourers		
Cheap labour availability		
Opposition from farm labourers		
Lack of skilled labourers for operating improved machinery		
Lack of awareness		

What is your perceived importance of the wetlands?
Very important = 5 Important = 5 Some what important = 3
Little importance = 2 Not important = 1

Statement	**5**	**4**	**3**	**2**	**1**
Wetland give higher yield					
Wetland is easier to work on					
Wetland makes farming more interesting					
Wetland conserves soil fertility					
Wetland is easy to manage in term of weed control					
Wetland looks more attractive					
Wetland is cheap to acquire					
There is less conflict on wetland					

Section 3

Constraints to adoption and continued adoption of sawah ecotechnology method of rice production in Nigeria.

1. **Identification of major constraints to sawah rice production**

Constraint	Yes	No
Small farm size (Land Tenure)		
Lack of co-operation among farmers		
Negative attitude towards		
High capital cost of improved farm implements/ machinery		
Mechanization		
High cost of operation		
Non-availability of suitable Implements		
Non-availability of spare parts		
Inadequate service and repair facilities		
High mechanical complexity of improved machinery		
Low custom hire facilities		
Lack of credit facilities		
Low profitability of rice cultivation		
Plentiful availability of human labourers		
Cheap labour availability		
Opposition from farm labourers		
Lack of skilled labourers for operating improved machinery		

2. Severity of major constraints to sawah rice production

(A) Land acquisition and tenure

Statement	Very severe	Severe	Not severe
Accessibility			
Availability			
Fertility			
Affordability			
Poor road network			
Topography			

Land conflict			
Land fragmentation			

(B) Production and on-farm issue

Statement	Very severe	Severe	Not severe
Flood			
Drought			
Weed			
Diseases and pest invasion			
Water management			
Poor land fertility			
Lower yield problem			

(A) Economic and Market

Statement	Very severe	Severe	Not sesvre
Lack of proper market facilities			
High fluctuation in market prices			
Minimum support price is not declared before sowing season			
Lack of export marketing in the area			
Glot during harvest			
Lack of middlemen in the area			
Small Scale of production			
lack of capital			
Non-availability of loans			
Lack of finance agencies			

(B) Input

Statement	Very severe	Severe	Not severe
Unavailability of improved varieties used for transplanted fennel			
More requirement of fertilizers and manure			
Unavailability of recommended chemicals			
Lack of irrigation water			
Unavailability of labour			
Lack of processing facility			
Power tiller			
High cost of inputs			

(C) Information and training needs

Statement	Very severe	Severe	Not severe
Large information need			
Lack of extension and advice on sawah technology			
Lack of practical farm demonstration			
Lack of training on sawah technology			
Training need of farmers and extension agents			
Lack of technical knowledge			
Lack of skill			
Poor media portrayal			

(D)

(E) Scientific, technological and technical constraints

Statement	Very severe	Severe	Not severe
Unavailability of technical guidance			
Lack of knowledge about nursery raising			
Lack of skill for seed and soil treatment			
Lack of need based training			
Lack of knowledge and skill about weed management			
Lack of knowledge about export quality produce			
Power tiller operation and maintenance			
Bonding			
Dyke construction			
Puddling			
Complexity of certain improved technologies			
Susceptibility of improved strains to pests and diseases			

(F) Attitude to and perception of innovation

Statement	Very severe	severe	Not severe
Perception of risk			
Perception of low profitability			
Non-perception of necessity for suitable technology			
Impact of beliefs and traditions			
Negative attitude towards innovation			
Farmers resistant to change			

3. Suggest possible solutions to these problems:
....
....
....
....
....
4. What are your coping strategies you have been using in combating these constraints?

Section4

Analysis of farmers' knowledge and identification of training and information needs of sawah rice farmers in Nigeria.

A. CROPPING PATTERN OF FARMERS
1. What method of cropping do you practice?(a) mono cropping (b) mixed cropping.
2. Do you nurse you rice before planting? (a) yes (b) no
3. Do you puddle your field before planting? (a) yes (b) no
4. Do you level your field before planting? (a) yes (b) no
5. Do you smoothening your field before planting? (a) yes (b) no

b. KNOWLEDGE OF SAWAH TECHNOLOGY AMONG RESPONDENTS
8. Which of this operation is carried out first: a. Puddling b. Site selction c harvesting.
9. The process of moving soil from upper part of the land to the lower part is called:
   a. Puddling b. Ploughing. C. Levelling.
10. Excess water in the basin can lead to a. Flooding. b. Fertilization c. Drought
11. The place where seedlings are first grown before transplanting is called. a. Field b. Farm c. Nursery
12. A land where sawah is practice is called a. Upland b. High land c. lowland
13. The place of introducing water to the basin is called a. Outlet b. Inlet c. flooding
14. Arrange the following operations as they are being carried out rice production:

Operations	**No 1,2,3,4.5...........13**
Milling	
Land clearing	
Site selection	
Land clearing	
Winnowing	
Drying	
Ploughing/Harrowing/puddling	
Threshing	
Transplanting	
Levelling	
Flooding	
Harvesting/cutting	
Packaging/storage	

c. SOURCES OF INFORMATION ON SAWAH.

Sources	**Yes**	**No**
Radio		
Internet		
Local T.V		
Fellow researchers		
Cable T.V		
Newspaper		
Periodicals		
Magazines		
Journals		
Friends/peers		
Farmers		
Training attended		
Workshop attended		
Posters and pamphlets		
Agricultural shows		
Group meetings		
Village head		
Contact farmers		
Extension agent		

d. TRAINING ATTENDED BY SAWAH RICE FARMERS

(A) Training Types

Training types	Yes	No	No of times attended
Training of trainers			
Short term courses			
On the job training			
Field visitation and observation			
Field days			
Seminars			
Workshops			

(B) Training Areas

Training Areas	Yes	No	No of times attended

Site Selection for sawah rice production			
Water sourcing			
Soil selection			
Sawah layout and design			
Power tiller operationand management			
Ploughing and puddling			
Surface levelling and smoothening			
Purchase of farm inputs for sawah development			
Weed control			
Fertilizer application			
Pest control			
Disease control			
Harvesting and processing			
Nutrient management			
Storage of yields			
Adding value to produce			
Water management			
Fertilizer usage			
Nursery management			
Other areas (specify)			

e. TRAINNING AREA NEEDED BY FARMERS TO IMPROVE PRODUCTIVITY

(A)Training Types

Training types	Yes	No	No of times attended
Training of trainers			
Short term courses			
On the job training			
Field visitation and observation			
Field days			
Seminars			
Workshops			

B). Training Areas

Training Areas	Yes	No
Site Selection for sawah rice production		
Water sourcing		
Soil selection		

Sawah layout and design		
Power tiller operationand management		
Ploughing and puddling		
Surface levelling and smoothening		
Purchase of farm inputs for sawah development		
Weed control		
Fertilizer application		
Pest control		
Disease control		
Harvesting and processing		
Nutrient management		
Storage of yields		
Adding value to produce		
Water management		
Fertilizer usage		
Nursery management		
Other areas (specify)		

f. CONTRAINT TO TRAININGS ON SAWAH TECHNOLOGY

CONSTRAINTS	YES	NO
Funding of training		
Notice of training		
Busy schedules		
Accessibility		
Language barrier/communication		
Non availability of training		
Training Do not meet my need		
Lack of training facilities		

Section 5

Assessment of Professional Competencies and Training Need of Extension Agents for Sustainable Sawah Development in Nigeria.

Dear Respondent,

This study is designed to investigate **Assessment of Professional Competencies and Training Need of Extension Agents for Sustainable Sawah Development in Nigeria.** Your honest and forthright response to this questionnaire will be highly appreciated. Assurance is being given that information supplied will be used strictly for academic and research purposes.
Thank you very much for your time.
ALARIMA C. I.

(A) PERSONAL INFORMATION/DEMOGRAPHIC CHARACTERISTICS OF RESPONDENT

1. Name of Respondent: ....
2. Sex: Male Female
3. Age in years:...
4. Residential marital status:(a) Married (b) single
5. Educational level: No formal education=1 Primary = 2 secondary School = 3 Tertiary = 4
6. Household size: .... Males .... Females ....
7. Number of Children in household: .... Males .... Females
8. Years of working experience...............................
9. Years of sawah experience.................................
10. Years of involvement in sawah research..............................
11. Institution: (a) university (b) research institution (c) ADP (d) Millennium village
12. How many years have you been growing rice? ....
13. What are the yields of your non Sawah farm? ....
14. How many years have you practised Sawah rice farming? ....
15. What are the yields of your Sawah farm? ....
16. Sawah Farm size in hectares...

(B) SOURCES OF INFORMATION ON SAWAH.

Sources	**Yes**	**No**
Radio		
Internet		
Local T.V		
Fellow researchers		
Cable T.V		
Newspaper		
Periodicals		
Magazines		
Journals		

Friends/peers		
Farmers		
Training attended		
Workshop attended		
Posters and pamphlets		
Agricultural shows		
Group meetings		
Village head		
Contact farmers		
Extension agent		

(C)TRAINING ATTENDED BY **AGRICULTURAL PROFESSIONALS**

(A) Training Types

Training types	Yes	No	No of times attended
Training of trainers			
Short term courses			
On the job training			
Field visitation and observation			
Field days			
Seminars			
Workshops			

(D) Training Areas

Training Areas	Yes	No	No of times attended
Site Selection for sawah rice production			
Water sourcing			
Soil selection			
Sawah layout and design			
Power tiller operationand management			
Ploughing and puddling			
Surface levelling and smoothening			
Purchase of farm inputs for sawah development			
Weed control			
Fertilizer application			
Pest control			
Disease control			
Harvesting and processing			
Nutrient management			

Storage of yields			
Adding value to produce			
Other areas (specify)			

(E) TRAINNING AREA NEEDED BY **AGRICULTURAL PROFESSIONALS**

(A)Training Types

Training types	Yes	No	No of times attended
Training of trainers			
Short term courses			
On the job training			
Field visitation and observation			
Field days			
Seminars			
Workshops			

(F) Training Areas

Training Areas	Yes	No
Site Selection for sawah rice production		
Water sourcing		
Soil selection		
Sawah layout and design		
Power tiller operationand management		
Ploughing and puddling		
Surface levelling and smoothening		
Purchase of farm inputs for sawah development		
Weed control		
Fertilizer application		
Pest control		
Disease control		
Harvesting and processing		
Nutrient management		
Storage of yields		
Adding value to produce		
Other areas (specify)		

(G) CONTRAINT TO TRAININGS ON SAWAH TECHNOLOGY

CONSTRAINTS	YES	NO
Funding of training		
Notice of training		
Busy schedules		
Accessibility		
Language barrier/communication		
Non availability of training		
Training Do not meet my need		
Lack of training facilities		

(H) Professional competencies required by the extension agents

Professional competencies	YES	NO
Conducting demonstration		
Communication Skill		
Farmers training		
Formation of farmers groups		
Farmer identification		
Selection of contact farmers		

(I) Preferred training methods used by the extension agents

Training methods	YES
On-the-job training	
Demonstration	
Field visitation and observation	
Workshop	
Group discussion	
Lecture	

APPENDIX 2

Analytical result of soil properties

a. Macro and micro elements

Parameter	Code
pH H2O	1
pH KCl	2
Electrical Conductivity (EC d s/m)	3
Exchangeable Calcium (cmol (+) kg^{-1})	4
Exchangeable Potassium (cmol (+) kg^{-1})	5
Exchangeable Magnesium (cmol (+) kg^{-1})	6
Exchangeable Sodium (cmol (+) kg^{-1})	7
Available Phosphorus (P_2O_5) (mg kg^{-1})	8
Available Silica (SiO_2) (mg kg^{-1})	9
Available Sulfur (mg kg^{-1})	10
Total Nitrogen (TN) (g kg^{-1})	11
Total Carbon (TC) (g kg^{-1})	12
C/N	13
Available Copper (mg kg^{-1})	14
Available Iron (mg kg^{-1})	15
Available Manganese (mg kg^{-1})	16
Available Nickel (mg kg^{-1})	17
Available Zinc(mg kg^{-1})	18
Clay (%)	19
Silt (%)	20
Coarse Sand (%)	21
Fine Sand (%)	22

Sand (%)	23

b. **Geochemical properties**

Parameter	Code
Total As (ppm)	24
Total Pb (ppm)	25
Total Zn(ppm)	26
Total Cu (ppm)	27
Total Ni (ppm)	28
Total Cr (ppm)	29
Total V (ppm)	30
Total Sr (ppm)	31
Total Y (ppm)	32
Total Nb (ppm)	33
Total Zr (ppm)	34
Total Th (ppm)	35
Total Sc (ppm)	36
Total TS (ppm)	37
Total F (ppm)	38
Total Br (ppm)	39
Total I (ppm)	40
Total SiO_2 (%)	41
Total TiO_2 (%)	42
Total Al_2O_3 (%)	43
Total Fe_2O_3 (%)	44
Total MnO (%)	45
Total MgO (%)	46
Total CaO (%)	47

Total Na_2O (%)	48
Total K_2O (%)	49
Total P_2O_5 (%)	50
Total	51
CIA	52

S/N	Pedon	Depth	1	2	3	4	5	6	7	8	9	10	11	12	13
1	AKR 1	0-15 cm	5.13	4.34	0.05	7.11	0.40	2.74	0.75	90.21	135.60	28.67	1.36	15.04	11.06
2		15-30 cm	5.18	4.85	0.07	6.11	0.32	3.02	1.34	35.57	222.29	32.98	0.64	6.46	10.09
3		30-45 cm	6.19	5.17	0.08	9.71	0.36	5.83	2.81	16.04	331.82	32.93	0.36	3.25	9.03
4		45-60 cm	6.56	5.42	0.07	7.60	0.33	5.92	3.00	12.56	374.06	20.91	0.30	2.68	8.93
5	AKR 2	0-15 cm	6.43	5.75	0.13	21.22	0.48	5.63	1.49	323.35	688.46	31.25	3.01	29.10	9.67
6		15-30 cm	6.64	5.60	0.08	13.21	0.42	4.12	1.39	550.41	556.42	24.55	2.11	21.05	9.98
7		30-45 cm	6.51	5.42	0.05	10.35	0.35	4.21	0.97	219.46	293.49	17.83	1.17	11.93	10.20
8		45-60 cm	6.50	5.35	0.04	11.37	0.38	4.80	1.08	134.26	302.49	16.13	0.95	9.11	9.59
9	EJT 1	0-15 cm	4.93	4.28	0.05	3.56	0.49	0.77	0.22	49.21	106.39	10.88	1.49	17.86	11.99
10		15-30 cm	4.92	3.97	0.02	2.89	0.29	0.84	0.26	32.37	128.36	7.81	0.70	9.50	13.57
11		30-45 cm	4.88	3.81	0.01	2.26	0.26	0.92	0.28	9.72	233.03	6.32	0.36	4.37	12.14
12		45-60 cm	4.61	3.51	0.01	1.98	0.29	0.91	0.35	9.11	167.65	5.11	0.28	2.89	10.32
13	EJT 2	0-15 cm	5.42	4.76	0.02	1.72	0.12	0.37	0.37	21.87	81.11	5.07	0.36	4.70	13.06
14		15-30 cm	5.77	4.51	0.02	2.05	0.12	0.61	0.97	2.29	112.23	5.11	0.17	1.62	9.52
15		30-45 cm	5.94	4.86	0.02	1.50	0.13	0.53	0.96	0.87	151.46	4.98	0.08	0.56	6.77
16		45-60 cm	6.00	4.60	0.02	1.33	0.15	0.54	1.07	3.32	97.39	4.10	0.06	0.37	6.22
17	EJT TRAD	0-15 cm	5.33	4.68	0.03	1.85	0.38	0.41	0.21	30.13	59.22	5.61	0.63	8.43	13.31
18		15-30 cm	5.24	4.34	0.02	1.31	0.19	0.27	0.24	7.90	61.38	5.02	0.19	2.38	12.59
19		30-45 cm	5.10	3.76	0.01	1.36	0.17	0.46	0.41	4.56	95.95	3.55	0.14	1.46	10.66
20		45-60 cm	4.92	3.64	0.01	0.81	0.18	0.38	0.38	1.95	101.26	2.46	0.11	0.84	7.52
21	EMR 1	0-15 cm	4.85	3.95	0.02	1.77	0.48	0.54	0.40	8.30	107.57	7.18	0.45	5.47	12.08
22		15-30 cm	4.91	3.88	0.02	3.65	0.53	1.02	0.89	4.89	122.44	12.08	0.36	3.26	9.15
23		30-45 cm	4.94	3.70	0.02	6.54	0.57	1.93	1.59	8.85	235.14	22.68	0.49	3.33	6.76
24		45-60 cm	4.81	3.65	0.02	8.03	0.64	2.56	2.02	10.12	223.38	15.57	0.43	2.93	6.82
25	EMR 2	0-15 cm	4.75	3.74	0.02	2.09	0.36	0.63	0.42	12.96	145.10	6.84	0.43	4.38	10.18
26		15-30 cm	5.10	3.96	0.02	4.56	0.33	1.16	0.90	5.41	256.73	10.90	0.40	3.36	8.40
27		30-45 cm	5.14	3.99	0.01	4.22	0.34	1.17	0.98	4.79	289.83	10.42	0.34	2.33	6.96

28		45-60 cm	5.26	3.96	0.01	5.28	0.38	1.69	1.48	4.74	316.23	8.15	0.31	2.10	6.86
29	EMR TRAD	0-15 cm	4.69	3.85	0.03	2.93	0.42	0.93	0.35	19.77	161.55	9.49	0.85	9.31	10.98
30		15-30 cm	4.78	3.89	0.02	4.36	0.29	1.19	0.43	4.29	258.23	9.25	0.37	2.80	7.64
31		30-45 cm	4.60	3.96	0.01	5.72	0.35	1.59	0.52	3.76	318.99	9.73	0.30	2.44	8.25
32		45-60 cm	5.04	3.96	0.01	8.99	0.46	2.65	0.72	5.68	299.16	9.76	0.18	1.13	6.31
33	ETS 1	0-15 cm	4.98	4.23	0.02	2.29	0.31	0.41	0.29	12.77	89.43	6.95	0.56	6.55	11.67
34		15-30 cm	5.01	4.11	0.01	2.05	0.39	0.40	0.28	6.12	85.89	5.32	0.22	2.55	11.72
35		30-45 cm	5.13	4.16	0.01	1.81	0.26	0.32	0.28	4.71	110.23	5.73	0.21	1.50	7.14
36		45-60 cm	5.22	4.14	0.01	2.05	0.25	0.40	0.24	5.33	195.84	7.04	0.19	1.21	6.37
37	ETS 2	0-15 cm	4.86	3.92	0.02	2.75	0.36	0.54	0.26	10.79	130.11	7.78	0.57	6.25	10.96
38		15-30 cm	4.91	3.78	0.01	1.58	0.24	0.28	0.18	6.85	184.29	5.83	0.43	4.00	9.30
39		30-45 cm	5.00	3.71	0.01	1.37	0.21	0.27	0.21	7.35	210.39	4.21	0.35	2.47	7.06
40		45-60 cm	5.06	3.65	0.01	0.98	0.19	0.20	0.19	5.78	232.49	3.94	0.37	2.26	6.11
41	ETS TRAD	0-15 cm	4.93	4.09	0.02	2.36	0.22	0.46	0.32	12.84	108.80	7.10	0.52	6.22	11.96
42		15-30 cm	5.17	3.98	0.01	1.78	0.20	0.42	0.33	7.96	103.97	5.49	0.20	1.54	7.70
43		30-45 cm	5.18	3.95	0.01	1.88	0.22	0.65	0.36	3.74	332.08	5.63	0.25	1.63	6.52
44		45-60 cm	5.19	3.88	0.01	3.23	0.26	1.18	0.43	4.33	227.83	4.32	0.29	1.80	6.21
45	ILA 1	0-15 cm	4.64	3.79	0.03	3.54	0.37	1.12	0.49	29.26	260.30	9.45	0.87	9.81	11.28
46		15-30 cm	4.42	4.08	0.01	3.16	0.31	1.02	0.58	7.42	157.24	6.07	0.34	3.66	10.76
47		30-45 cm	4.70	4.36	0.01	2.86	0.35	1.04	0.81	6.14	127.50	5.25	0.17	1.76	10.35
48		45-60 cm	5.04	4.34	0.01	3.38	0.37	1.28	1.07	5.06	168.97	5.27	0.21	2.11	10.05
49	ILA 2	0-15 cm	4.79	4.02	0.01	2.74	0.58	0.79	0.41	4.36	174.44	5.85	0.29	3.05	10.52
50		15-30 cm	4.75	3.90	0.01	2.04	0.24	0.67	0.56	9.41	201.95	6.57	0.47	4.87	10.36
51		30-45 cm	4.52	3.84	0.03	2.04	0.28	0.80	0.77	2.39	222.25	10.40	1.13	12.90	11.42
52		45-60 cm	4.97	3.98	0.01	1.84	0.30	0.80	0.86	4.54	133.16	5.38	0.22	2.78	12.64
53	ILA 3	0-15 cm	4.63	3.91	0.04	1.47	0.27	0.62	0.16	54.95	24.65	9.87	1.27	14.94	11.76
54		15-30 cm	4.62	3.79	0.01	1.56	0.12	0.75	0.13	33.54	123.44	6.24	0.53	6.14	11.58
55		30-45 cm	4.99	4.05	0.02	1.45	0.10	0.73	0.13	2.60	175.96	18.05	0.28	2.86	10.21

56		45-60 cm	5.01	4.10	0.05	2.15	0.12	1.13	0.22	2.48	172.24	47.73	0.24	2.65	11.04
57	NSF 1	0-15 cm	6.11	4.55	0.02	2.34	0.13	1.19	0.28	6.95	28.25	3.56	0.24	3.85	16.04
58		15-30 cm	5.34	4.20	0.01	2.22	0.15	1.03	0.25	3.40	32.41	3.81	0.15	1.32	8.80
59		30-45 cm	5.22	4.50	0.01	2.38	0.26	1.00	0.17	2.55	51.52	3.80	0.11	0.84	7.64
60		45-60 cm	5.33	4.58	0.01	2.26	0.13	1.14	0.32	3.57	31.19	3.13	0.08	0.78	9.75
61	NSF TRAD	0-15 cm	5.20	4.57	0.01	2.20	0.26	0.94	0.16	2.11	15.84	2.94	0.20	2.35	11.75
62		15-30 cm	5.03	5.03	0.01	1.57	0.14	0.75	0.27	1.17	9.51	2.53	0.09	1.02	11.33
63		30-45 cm	5.19	4.33	0.01	1.86	0.12	0.99	0.55	0.09	24.47	2.19	0.07	0.61	8.71
64		45-60 cm	5.06	4.32	0.01	1.76	0.14	1.04	1.08	-0.18	41.68	2.01	0.04	0.35	8.75
65	SHB 1	0-15 cm	4.98	4.65	0.03	1.83	0.19	0.89	0.16	32.59	63.42	6.71	0.60	7.37	12.28
66		15-30 cm	5.05	4.96	0.01	1.43	0.11	0.70	0.11	4.62	11.72	2.15	0.06	0.81	13.50
67		30-45 cm	5.18	5.08	0.01	0.82	0.09	0.44	0.17	5.06	7.93	2.32	0.08	0.90	11.25
68		45-60 cm	5.15	5.24	0.01	0.87	0.12	0.42	0.31	2.62	15.83	1.97	0.05	0.63	12.60
69	SHB TRAD	0-15 cm	4.69	3.89	0.01	1.52	0.25	0.59	0.20	1.51	19.45	2.48	0.17	1.77	10.41
70		15-30 cm	4.83	4.33	0.01	1.97	0.17	0.92	0.26		9.26	2.44	0.05	0.60	12.00
71		30-45 cm	4.78	4.34	0.01	2.04	0.17	1.05	0.39	0.12	16.91	1.93	0.04	0.47	11.75
72		45-60 cm	4.72	4.34	0.00	2.51	0.21	1.44	0.59	1.11	8.61	1.83	0.03	0.30	10.00
73	ZNK 1	0-15 cm	6.82	4.24	0.02	5.79	0.60	1.73	0.56	15.85	53.24	6.33	0.57	7.20	12.63
74		15-30 cm	6.27	4.15	0.01	4.95	0.38	1.28	0.76	5.66	94.50	8.73	0.33	3.02	9.15
75		30-45 cm	6.34	4.11	0.02	4.69	0.32	1.23	1.01	3.79	227.91	12.44	0.35	2.69	7.69
76		45-60 cm	6.14	4.20	0.02	4.19	0.32	1.15	1.33	4.21	213.01	12.47	0.34	2.64	7.76
77	ZNK 2	0-15 cm	5.08	4.42	0.02	0.58	0.13	0.13	0.09	19.03	39.73	10.44	0.71	9.38	13.21
78		15-30 cm	5.82	5.20	0.03	0.78	0.09	0.17	0.09	7.43	74.81	7.60	0.22	2.11	9.59
79		30-45 cm	7.61	6.35	0.14	0.82	0.10	0.23	0.09	5.13	292.42	8.97	0.12	1.04	8.67
80		45-60 cm	8.96	6.92	0.30	0.56	0.08	0.16	0.09	5.17	420.98	11.42	0.15	1.28	8.53
81	ZNK TRAD	0-15 cm	4.91	4.17	0.02	0.31	0.10	0.07	0.10	11.34	35.51	4.55	0.61	7.62	12.49
82		15-30 cm	5.22	4.55	0.01	0.23	0.07	0.05	0.08	5.21	35.51	5.17	0.21	2.13	10.14
83		30-45 cm	5.55	4.72	0.01	0.20	0.07	0.04	0.09	4.06	141.22	7.66	0.27	2.68	9.93

84		45-60 cm	5.49	4.66	0.02	0.21	0.06	0.04	0.09	3.79	158.81	8.43	0.28	2.74	9.79
85	ISH 1	0-15 cm	4.76	4.12	0.03	1.37	0.50	0.35	0.27	34.54	55.01	8.39	0.94	10.37	11.03
86		15-30 cm	5.05	4.10	0.01	0.37	0.11	0.09	0.14	1.40	45.31	5.72	0.36	3.59	9.97
87		30-45 cm	4.96	4.01	0.01	0.30	0.13	0.06	0.15	1.01	61.72	5.27	0.26	2.57	9.88
88		45-60 cm	5.23	3.91	0.01	0.29	0.16	0.07	0.16	1.03	76.02	4.26	0.27	3.64	13.48
89	ISH 2	0-15 cm	4.71	3.73	0.02	0.57	0.16	0.11	0.14	20.58	77.98	6.75	0.93	10.23	11.00
90		15-30 cm	4.79	3.78	0.01	0.39	0.14	0.10	0.15	2.10	86.16	5.89	0.58	6.07	10.47
91		30-45 cm	4.91	3.75	0.01	0.32	0.13	0.09	0.15	2.22	105.51	6.47	0.53	5.51	10.40
92		45-60 cm	4.94	3.74	0.02	0.28	0.14	0.07	0.17	2.66	83.27	9.04	0.45	4.20	9.33
93	ISH TRAD	0-15 cm	4.67	3.87	0.02	1.43	0.19	0.34	0.48	12.64	73.38	8.62	0.85	9.11	10.72
94		15-30 cm	5.02	3.84	0.02	4.26	0.29	0.53	2.41	5.59	-3.18	8.54	0.75	7.43	9.91
95		30-45 cm	5.22	3.83	0.02	4.50	0.31	0.56	2.60	3.65	185.48	14.22	0.48	4.57	9.52
96		45-60 cm	5.14	3.80	0.03	8.80	0.74	1.08	4.10	2.94	110.86	26.09	0.44	4.37	9.93
97	SHE 1	0-15 cm	5.25	4.03	0.01	2.32	0.15	0.43	0.22	5.46	54.62	5.15	0.33	3.66	11.09
98		15-30 cm	5.86	4.85	0.03	2.01	0.19	0.33	0.27	3.13	192.63	6.29	0.26	1.86	7.15
99		30-45 cm	6.62	5.90	0.06	3.19	0.23	0.59	0.40	1.85	416.37	7.64	0.16	1.18	7.38
100		45-60 cm	7.16	6.09	0.06	3.53	0.25	0.70	0.48	2.69	429.27	8.88	0.11	0.72	6.55
101	SHE 2	0-15 cm	5.97	4.05	0.01	1.50	0.13	0.31	0.16	6.06	74.36	6.24	0.29	2.94	10.14
102		15-30 cm	5.38	3.95	0.01	2.11	0.18	0.42	0.52	4.79	105.10	5.47	0.22	1.71	7.77
103		30-45 cm	5.27	3.90	0.01	2.97	0.25	0.69	0.83	5.23	190.69	7.96	0.28	1.90	6.79
104		45-60 cm	5.21	3.85	0.01	4.17	0.38	1.05	1.31	6.24	229.60	8.45	0.31	1.75	5.65
105	SHE TRAD	0-15 cm	4.85	4.15	0.02	2.42	0.18	0.39	0.28	9.35	29.01	6.97	0.61	7.11	11.66
106		15-30 cm	5.35	4.00	0.01	4.40	0.23	0.72	0.41	6.33	127.02	5.90	0.27	1.85	6.85
107		30-45 cm	5.31	4.03	0.01	7.20	0.35	1.35	0.73	5.38	176.50	9.19	0.32	2.11	6.59
108		45-60 cm	5.41	4.05	0.01	8.63	0.42	1.73	0.89	5.00	251.39	10.36	0.29	1.84	6.34
109	ETD 1	0-15 cm	4.75	3.96	0.03	3.58	0.21	0.54	0.29	63.25	224.34	8.06	0.64	7.22	11.28
110		15-30 cm	4.28	3.92	0.02	3.27	0.27	0.61	0.82	73.40	256.58	8.10	0.49	6.43	13.12
111		30-45 cm	4.39	3.94	0.01	5.10	0.37	0.60	2.87	1.70	181.94	4.13	0.26	4.12	15.85

112		45-60 cm	4.26	3.85	0.01	1.51	0.19	0.26	0.38	1.55	142.24	3.28	0.22	2.66	12.09
113	ETD TRAD	0-15 cm	4.26	3.85	0.03	2.23	0.21	0.31	0.45	74.83	325.71	15.42	0.93	9.66	10.39
114		15-30 cm	4.00	3.56	0.02	4.90	0.32	0.88	1.09	86.07	337.46	11.81	0.80	8.59	10.74
115		30-45 cm	4.02	3.54	0.01	6.44	0.42	1.18	1.45	27.61	173.03	5.52	0.37	4.80	12.97
116		45-60 cm	4.04	3.60	0.01	12.52	0.62	0.81	7.75	19.19	148.84	3.65	0.24	3.08	12.83

S/N	Pedon	Depth	14	15	16	17	18	19	20	21	22	23
1	AKR 1	0-15 cm	2.82	275.60	49.33	1.56	5.83	23.89	12.88	35.95	27.28	63.23
2		15-30 cm	1.21	42.10	31.68	1.03	0.36	25.57	9.22	37.70	27.50	65.21
3		30-45 cm	0.52	18.20	16.15	0.19	0.17	23.96	14.58	35.83	25.63	61.46
4		45-60 cm	0.37	15.19	6.28	0.08	0.10	26.96	10.12	40.92	22.00	62.92
5	AKR 2	0-15 cm	1.88	84.84	31.84	1.11	4.68	34.64	20.31	12.24	32.81	45.05
6		15-30 cm	2.26	144.66	36.11	1.48	3.78	30.02	18.70	20.71	30.56	51.27
7		30-45 cm	2.02	112.12	35.56	1.01	1.23	25.44	11.88	24.32	38.36	62.68
8		45-60 cm	1.77	69.13	30.17	0.59	0.70	26.45	14.81	20.68	38.07	58.75
9	EJT 1	0-15 cm	1.82	425.05	51.09	0.57	1.20	22.75	52.94	1.31	23.00	24.31
10		15-30 cm	2.31	238.18	56.38	0.56	0.55	27.81	46.66	4.36	21.17	25.53
11		30-45 cm	1.89	128.26	89.41	0.52	0.33	33.54	38.70	6.00	21.76	27.76
12		45-60 cm	1.97	130.43	110.74	0.55	0.29	39.93	35.72	2.85	21.50	24.35
13	EJT 2	0-15 cm	0.49	94.24	66.31	0.32	0.23	5.38	14.75	26.14	53.73	79.86
14		15-30 cm	0.60	38.28	32.20	0.25	0.04	11.89	15.72	23.31	49.08	72.39
15		30-45 cm	0.37	13.53	14.60	0.13	-0.01	10.35	13.03	21.97	54.65	76.62
16		45-60 cm	0.40	14.10	15.48	0.14	0.02	10.97	10.42	24.83	53.77	78.60
17	EJT TRAD	0-15 cm	0.59	142.72	17.04	0.19	0.87	11.13	25.07	9.97	53.83	63.80
18		15-30 cm	0.73	90.60	13.22	0.18	0.22	12.68	18.51	34.46	34.35	68.81
19		30-45 cm	0.87	77.44	26.35	0.34	0.19	21.36	28.06	5.53	45.05	50.58
20		45-60 cm	0.80	55.56	48.87	0.39	0.21	26.25	24.83	3.69	45.23	48.92
21	EMR 1	0-15 cm	2.36	186.08	88.56	0.36	0.28	22.79	29.45	4.17	43.58	47.75
22		15-30 cm	1.95	130.78	111.04	0.51	0.24	33.83	18.02	13.83	34.31	48.15
23		30-45 cm	1.33	28.86	93.32	0.69	0.23	74.14	10.15	2.08	13.63	15.71
24		45-60 cm	1.34	15.75	43.26	0.61	0.22	71.76	11.13	2.81	14.30	17.11
25	EMR 2	0-15 cm	2.67	186.30	62.03	0.37	0.53	25.60	13.95	15.88	44.58	60.46
26		15-30 cm	1.68	33.37	67.98	0.49	0.23	43.37	12.84	13.56	30.23	43.79
27		30-45 cm	1.41	22.72	36.47	0.42	0.18	43.35	12.23	12.98	31.43	44.41

28		45-60 cm	1.43	28.20	31.33	0.38	0.21	41.83	17.40	9.66	31.11	40.77
29	EMR TRAD	0-15 cm	3.74	303.84	98.01	0.75	1.13	18.26	31.36	2.05	48.32	50.37
30		15-30 cm	2.13	54.40	90.56	0.49	0.27	35.66	19.11	9.99	35.25	45.23
31		30-45 cm	2.04	39.98	53.93	0.47	0.26	40.72	17.98	10.88	30.42	41.30
32		45-60 cm	1.81	31.49	47.03	0.43	0.28	42.96	15.73	10.47	30.84	41.31
33	ETS 1	0-15 cm	2.84	106.77	71.04	0.78	0.26	14.99	27.30	5.72	52.00	57.72
34		15-30 cm	1.66	21.47	46.80	0.34	0.03	17.05	24.61	11.00	47.34	58.34
35		30-45 cm	0.91	12.80	21.51	0.31	0.04	21.73	11.64	44.05	22.59	66.64
36		45-60 cm	0.95	11.35	28.16	0.56	0.12	33.07	9.62	33.37	23.93	57.31
37	ETS 2	0-15 cm	3.27	79.51	80.74	0.52	0.15	36.36	28.36	1.11	34.17	35.28
38		15-30 cm	2.29	54.30	52.85	0.60	0.14	40.05	24.05	0.98	34.92	35.90
39		30-45 cm	1.54	28.19	45.81	0.65	0.13	43.31	14.69	4.24	37.76	41.99
40		45-60 cm	1.57	21.17	43.39	0.80	0.18	52.24	10.41	4.27	33.08	37.35
41	ETS TRAD	0-15 cm	3.74	113.14	60.45	0.49	0.15	24.68	17.13	0.83	57.36	58.19
42		15-30 cm	1.25	25.84	25.23	0.31	0.03	24.04	11.64	4.26	60.07	64.32
43		30-45 cm	0.95	17.45	28.43	0.39	0.05	31.17	11.21	11.55	46.07	57.62
44		45-60 cm	0.93	12.39	29.43	0.41	0.07	38.78	10.96	7.50	42.76	50.26
45	ILA 1	0-15 cm	2.99	451.03	97.52	0.89	1.09	16.91	14.64	41.01	27.44	68.45
46		15-30 cm	1.85	78.14	36.44	0.39	0.37	15.51	12.62	32.55	39.31	71.86
47		30-45 cm	1.04	33.90	30.88	0.19	0.16	12.40	10.98	41.63	34.99	76.62
48		45-60 cm	1.49	38.32	35.88	0.20	0.19	18.33	17.79	30.53	33.35	63.88
49	ILA 2	0-15 cm	2.40	63.05	24.61	0.46	0.26	20.97	24.43	25.54	29.06	54.60
50		15-30 cm	2.12	90.67	50.53	0.70	0.47	25.66	20.01	24.94	29.38	54.33
51		30-45 cm	4.12	394.76	83.19	0.94	1.28	26.50	20.34	22.66	30.50	53.17
52		45-60 cm	2.52	75.78	24.79	0.57	0.19	18.80	22.22	33.04	25.93	58.97
53	ILA 3	0-15 cm	4.09	358.08	61.44	0.93	1.32	29.50	15.37	24.44	30.69	55.13
54		15-30 cm	3.41	168.11	59.29	0.80	0.82	26.52	16.74	26.57	30.17	56.74
55		30-45 cm	1.74	54.09	29.89	0.48	0.28	24.39	14.83	36.58	24.20	60.77

56		45-60 cm	1.88	54.70	45.95	0.63	0.29	26.34	18.07	26.78	28.81	55.59
57	NSF 1	0-15 cm	0.43	41.41	9.27	0.08	0.07	13.07	10.95	38.13	37.85	75.97
58		15-30 cm	0.68	25.78	12.89	0.08	0.03	17.61	9.12	35.86	37.41	73.27
59		30-45 cm	0.46	8.88	8.41	0.05	0.02	7.86	13.24	40.64	38.26	78.90
60		45-60 cm	0.32	5.91	10.23	0.04	0.15	5.28	15.02	60.63	19.07	79.70
61	NSF TRAD	0-15 cm	0.27	39.52	5.08	0.05	0.05	3.05	6.63	38.99	51.34	90.33
62		15-30 cm	0.29	23.06	4.07	0.03	0.01	2.66	6.70	45.91	44.73	90.64
63		30-45 cm	0.27	12.07	3.67	0.02	0.00	1.43	11.59	41.51	45.47	86.98
64		45-60 cm	0.10	6.48	3.11	0.00	0.00	3.54	7.88	42.48	46.10	88.58
65	SHB 1	0-15 cm	1.06	270.58	27.87	0.52	1.32	16.15	19.13	33.20	31.53	64.72
66		15-30 cm	0.15	29.22	3.17	0.04	0.09	6.56	9.06	62.44	21.95	84.39
67		30-45 cm	0.14	32.06	3.55	0.05	0.16	4.44	7.11	68.12	20.33	88.45
68		45-60 cm	0.19	19.50	5.05	0.07	0.12	5.90	11.18	52.42	30.50	82.92
69	SHB TRAD	0-15 cm	0.14	21.25	0.48	0.04	0.01	4.84	3.79	63.25	28.12	91.37
70		15-30 cm	0.12	4.67	0.21	0.02	-0.02	4.47	5.43	62.11	27.99	90.10
71		30-45 cm	0.09	4.05	0.35	0.02	0.00	4.23	4.31	64.95	26.51	91.46
72		45-60 cm	0.05	2.56	0.44	0.02	0.05	4.18	2.78	69.85	23.19	93.04
73	ZNK 1	0-15 cm	0.54	175.52	12.39	0.18	0.07	13.37	9.18	24.89	52.55	77.44
74		15-30 cm	0.36	22.26	7.58	0.00	0.01	23.11	7.04	25.87	43.98	69.85
75		30-45 cm	0.23	8.75	4.14	-0.03	0.03	38.11	10.97	29.32	21.60	50.93
76		45-60 cm	0.19	7.53	3.09	-0.02	0.00	38.37	9.62	26.13	25.89	52.02
77	ZNK 2	0-15 cm	0.69	141.13	15.76	0.29	0.21	6.03	11.98	19.87	62.12	81.99
78		15-30 cm	0.32	12.37	8.05	0.09	0.00	8.86	7.44	20.05	63.65	83.69
79		30-45 cm	0.35	5.28	1.96	0.06	0.02	12.94	8.91	15.27	62.88	78.15
80		45-60 cm	0.43	2.75	2.42	0.05	0.01	14.89	10.61	18.37	56.13	74.49
81	ZNK TRAD	0-15 cm	0.51	186.89	9.16	0.14	0.11	10.13	10.49	20.36	59.02	79.38
82		15-30 cm	0.35	42.13	2.55	0.03	0.05	12.88	8.92	21.29	56.90	78.20
83		30-45 cm	0.38	26.52	3.34	0.04	0.02	29.62	10.09	17.24	43.05	60.28

84		45-60 cm	0.37	22.28	1.96	0.04	0.07	29.09	5.72	9.45	55.74	65.19
85	ISH 1	0-15 cm	1.25	285.94	67.93	0.71	0.62	18.95	13.21	12.17	55.67	67.84
86		15-30 cm	0.93	60.17	42.75	0.50	0.20	11.71	11.71	14.84	61.74	76.58
87		30-45 cm	0.87	32.40	35.85	0.62	0.26	10.46	15.29	16.87	57.37	74.25
88		45-60 cm	0.95	34.32	27.21	0.88	0.49	11.10	14.53	11.68	62.69	74.37
89	ISH 2	0-15 cm	2.39	283.08	62.18	0.80	1.07	20.16	24.42	3.15	52.27	55.42
90		15-30 cm	2.11	134.07	81.18	1.12	1.00	19.77	27.55	3.06	49.62	52.68
91		30-45 cm	2.18	119.35	54.23	1.45	1.23	21.78	28.78	4.26	45.18	49.44
92		45-60 cm	1.75	70.30	46.46	1.57	1.21	24.79	25.66	6.41	43.15	49.55
93	ISH TRAD	0-15 cm	2.01	130.13	67.73	0.74	0.72	22.87	31.50	0.87	44.76	45.63
94		15-30 cm	2.03	114.81	93.82	1.05	0.74	24.95	31.38	1.65	42.03	43.68
95		30-45 cm	1.41	81.96	82.57	1.07	0.60	17.88	27.52	4.15	50.45	54.60
96		45-60 cm	1.32	81.81	81.19	1.09	0.66	17.45	27.23	3.33	51.99	55.32
97	SHE 1	0-15 cm	1.07	76.32	45.83	0.26	0.08	7.51	19.40	23.08	50.02	73.09
98		15-30 cm	0.76	12.36	9.41	0.07	0.02	21.93	11.29	34.15	32.64	66.79
99		30-45 cm	0.53	3.04	4.10	0.11	0.02	23.78	11.01	30.19	35.02	65.21
100		45-60 cm	0.48	3.72	5.78	0.05	0.06	27.82	14.62	23.46	34.10	57.56
101	SHE 2	0-15 cm	1.41	51.97	27.00	0.24	0.07	19.40	16.98	13.69	49.93	63.62
102		15-30 cm	0.93	21.28	25.74	0.24	0.05	22.38	11.19	22.71	43.72	66.43
103		30-45 cm	0.93	14.30	42.94	0.42	0.42	32.44	9.70	23.22	34.64	57.86
104		45-60 cm	0.78	13.64	71.75	0.52	0.18	38.15	10.43	17.69	33.73	51.42
105	SHE TRAD	0-15 cm	1.11	93.90	15.47	0.23	0.11	10.77	17.19	9.24	62.80	72.04
106		15-30 cm	0.77	14.37	21.57	0.22	0.05	25.32	8.29	26.30	40.09	66.39
107		30-45 cm	0.76	12.16	19.24	0.29	0.05	27.37	14.34	20.95	37.34	58.29
108		45-60 cm	0.63	9.09	25.97	0.33	0.35	31.13	11.10	21.58	36.19	57.77
109	ETD 1	0-15 cm	1.53	345.41	99.12	0.54	1.09	15.96	23.95	3.24	56.85	60.09
110		15-30 cm	1.55	502.38	103.31	0.48	0.88	13.95	23.03	4.05	58.97	63.02
111		30-45 cm	1.10	100.99	55.97	0.35	0.30	15.69	24.40	8.24	51.67	59.91

112		45-60 cm	1.08	92.88	40.35	0.41	0.22	13.55	25.48	9.47	51.49	60.96
113	ETD TRAD	0-15 cm	5.84	350.16	165.92	1.16	2.57	12.69	28.03	6.60	52.69	59.29
114		15-30 cm	2.18	325.67	118.05	1.14	2.24	18.08	18.36	9.74	53.82	63.56
115		30-45 cm	1.71	192.09	64.84	0.68	1.11	18.87	16.07	15.75	49.30	65.05
116		45-60 cm	1.33	152.06	49.88	0.55	0.75	13.02	17.24	25.13	44.61	69.74

S/N	Pedon	LOI	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	AKR 1	4.49	1.70	19.10	38.80	16.10	27.00	63.40	392.00	129.70	13.56	34.00	576.70	15.00	12.00	689.00	190.00	2.40	
2	AKR 2	9.26	2.20	24.30	49.80	22.50	39.80	71.90	354.40	180.30	20.42	35.40	688.90	22.70	15.00	882.00		5.80	2.30
3	EJT 1	5.56	3.30	34.20	22.40	11.50	20.10	63.60	166.90	53.00	41.14	42.30	1080.70	28.70	5.60	499.00	202.00	2.00	15.50
4	EJT 2	1.63	3.70	19.30	13.30	6.30	6.60	64.20	86.50	23.00	23.42	21.40	1120.70	16.80	0.80	367.00	47.00	1.60	38.90
5	EJT TRAD	2.95	2.10	25.90	15.10	5.30	7.70	49.60	99.70	33.80	28.60	27.80	1247.10	18.70	1.90	402.00	225.00	1.70	29.80
6	EMR 1	3.19	2.70	21.50	18.40	12.40	11.40	59.60	127.80	63.30	27.06	23.30	812.00	16.90	3.70	354.00		1.60	19.10
7	EMR 2	3.47	3.20	18.20	18.60	12.40	14.40	78.80	153.50	47.10	21.98	17.80	675.00	13.40	10.00	364.00	145.00	1.70	23.40
8	EMR TRAD	4.15	3.00	22.70	21.30	16.10	15.80	76.20	158.90	76.10	32.03	26.40	945.90	20.50	8.40	406.00		1.50	18.50
9	ETS 1	3.14	3.00	24.00	17.00	13.30	17.70	51.00	96.50	48.80	41.40	28.20	946.90	24.60	4.50	373.00	75.00	1.80	
10	ETS 2	5.13	3.70	27.70	23.10	21.50	32.70	81.80	141.40	65.80	47.33	35.40	724.20	35.70	9.50	338.00	116.00	1.70	15.50
11	ETS TRAD	4.00	1.60	26.70	18.10	17.30	23.70	58.10	103.70	62.20	43.88	26.70	871.70	27.50	7.20	349.00	238.00	1.80	18.80
12	ILA 1	4.02	3.00	19.40	25.70	15.20	22.70	105.20	253.00	49.40	25.62	31.10	929.40	17.10	8.30	450.00	145.00	2.10	17.90
13	ILA 2	3.28	4.20	19.90	22.10	20.60	18.30	96.90	256.50	54.50	33.94	36.20	956.50	19.90	6.60	327.00		1.70	14.00
14	ILA 3	4.66	3.20	20.50	25.30	20.50	27.90	94.10	227.80	59.50	29.16	32.20	917.70	17.00	9.10	502.00		2.20	25.60
15	NSF 1	1.24	2.20	18.10	11.50	5.90	3.30	69.00	52.70	36.30	19.10	14.90	836.20	13.40		339.00	62.00	1.60	39.90
16	NSF TRAD	**0.71**	2.70	16.80	10.90	2.60	2.40	69.00	62.10	36.20	17.61	14.60	1046.50	14.50		340.00	75.00	1.80	42.00
17	SHB 1	2.51	2.60	24.60	16.40	5.50	8.70	52.90	85.50	34.20	27.76	22.30	1020.80	19.40	2.60	418.00		1.50	27.70
18	SHB TRAD	0.56	1.70	11.40	11.00	0.90	3.20	40.80	30.50	11.50	11.78	10.10	682.40	8.30		325.00	117.00	1.80	42.40
19	ZNK 1	2.53	2.20	31.20	17.00	3.40	8.30	36.80	58.50	177.60	30.49	11.50	512.80	11.10	0.70	408.00	36.00	1.80	24.70
20	ZNK 2	2.64	2.80	25.80	16.20	6.30	4.90	46.00	55.20	160.90	23.42	13.00	721.30	10.40		475.00	35.00	1.90	26.80
21	ZNK TRAD	2.58	2.60	28.70	14.80	5.10	5.30	31.80	41.50	174.20	24.03	11.30	569.70	10.60		395.00	258.00	1.90	24.50
22	ISH 1	2.84	3.70	14.60	22.50	6.90	12.80	46.00	68.30	73.50	23.60	15.20	873.50	10.10	2.90	481.00	115.00	2.50	27.50
23	ISH 2	3.35	3.50	18.60	27.40	12.00	19.10	50.50	98.40	88.50	27.54	18.20	699.60	12.50	3.60	424.00	248.00	2.00	16.90
24	ISH TRAD	3.45	4.50	22.30	28.30	10.80	17.60	52.60	105.50	97.80	30.80	21.40	693.30	14.20	5.10	409.00	172.00	2.10	15.40
25	SHE 1	1.59	2.10	19.40	13.20	9.20	6.40	61.80	87.00	66.70	22.90	16.50	795.40	13.10	2.00	345.00	264.00	1.50	30.70
26	SHE 2	2.52	2.20	19.80	16.30	7.30	12.60	75.10	113.50	66.60	23.64	19.80	666.50	15.50	6.90	336.00	102.00	1.70	26.10
27	SHE TRAD	2.00	2.30	19.50	13.60	5.60	6.70	66.20	86.90	84.80	23.74	18.90	871.10	13.80	1.90	391.00	11.00	1.60	26.40

28	ETD 1	3.38	4.70	25.80	19.60	9.80	14.40	60.10	161.70	24.40	34.70	34.50	1281.20	24.00	4.30	396.00	267.00	1.90	21.40
29	ETD TRAD	4.22	5.10	25.10	22.60	22.20	19.10	66.20	165.50	24.90	33.81	33.70	1244.40	24.00	5.20	461.00	101.00	3.20	17.10

S/N	Pedon	41	42	43	44	45	46	47	48	49	50	51	52
1	AKR 1	73.77	6.39	8.96	8.03	0.10	0.45	1.09	0.58	0.56	0.07	0.80	80.07
2	AKR 2	67.57	5.04	13.61	9.18	0.27	0.70	1.83	0.62	0.93	0.23	0.80	80.09
3	EJT 1	85.77	2.29	8.87	1.48	0.03	0.13	0.19	0.21	0.99	0.05	0.86	86.45
4	EJT 2	94.26	1.25	2.60	1.05	0.04	0.07	0.12	0.18	0.42	0.01	0.78	78.40
5	EJT TRAD	92.63	1.60	3.92	0.75	0.02	0.08	0.12	0.19	0.66	0.02	0.80	80.04
6	EMR 1	86.98	1.49	7.72	1.74	0.04	0.12	0.25	0.33	1.31	0.02	0.80	80.39
7	EMR 2	87.07	1.02	7.85	2.58	0.03	0.12	0.21	0.26	0.84	0.02	0.86	85.66
8	EMR TRAD	84.83	1.79	8.96	2.09	0.05	0.15	0.37	0.36	1.39	0.02	0.81	80.87
9	ETS 1	89.49	1.48	6.40	0.96	0.04	0.11	0.15	0.21	1.14	0.02	0.81	81.13
10	ETS 2	80.24	1.73	13.63	2.07	0.04	0.17	0.20	0.26	1.63	0.03	0.87	86.71
11	ETS TRAD	84.84	1.35	10.22	1.43	0.04	0.13	0.17	0.26	1.55	0.02	0.84	83.75
12	ILA 1	88.36	1.54	6.10	3.13	0.05	0.13	0.17	0.22	0.29	0.04	0.90	90.03
13	ILA 2	84.49	2.18	7.87	4.21	0.07	0.19	0.20	0.23	0.51	0.04	0.89	89.26
14	ILA 3	88.65	1.62	6.91	1.85	0.04	0.14	0.20	0.24	0.32	0.03	0.90	90.09
15	NSF 1	94.47	0.97	2.89	0.49	0.02	0.06	0.09	0.19	0.81	0.01	0.73	72.58
16	NSF TRAD	96.12	0.77	1.90	0.36	0.02	0.04	0.08	0.17	0.53	0.00	0.71	70.78
17	SHB 1	91.32	1.25	5.34	0.90	0.02	0.08	0.08	0.18	0.82	0.02	0.83	83.10
18	SHB TRAD	97.61	0.44	1.23	0.23	0.01	0.05	0.05	0.15	0.23	0.00	0.74	73.87
19	ZNK 1	82.05	0.60	10.38	1.77	0.03	0.16	0.34	0.71	3.96	0.01	0.67	67.45
20	ZNK 2	85.51	0.66	8.37	1.37	0.03	0.14	0.42	0.73	2.76	0.01	0.68	68.18
21	ZNK TRAD	83.58	0.58	9.74	1.18	0.02	0.11	0.33	0.72	3.72	0.01	0.67	67.14
22	ISH 1	88.25	0.72	6.58	2.34	0.03	0.21	0.22	1.22	0.40	0.04	0.78	78.24
23	ISH 2	84.38	0.89	9.11	3.15	0.02	0.28	0.22	1.24	0.67	0.04	0.81	81.00

24	ISH TRAD	81.08	1.07	10.96	3.59	0.05	0.36	0.29	1.53	1.03	0.05	0.79	79.39
25	SHE 1	90.37	1.10	4.96	1.56	0.18	0.08	0.26	0.31	1.17	0.01	0.74	74.08
26	SHE 2	88.18	1.17	7.32	1.41	0.03	0.11	0.29	0.31	1.18	0.01	0.81	80.53
27	SHE TRAD	90.03	1.33	5.35	1.01	0.04	0.09	0.32	0.35	1.48	0.01	0.71	71.29
28	ETD 1	88.03	1.92	6.74	2.50	0.04	0.11	0.10	0.17	0.36	0.04	0.92	91.50
29	ETD TRAD	85.99	1.84	7.98	3.23	0.05	0.11	0.11	0.23	0.41	0.05	0.91	91.40

List of Publications

1. Factors affecting the adoption of sawah technology system of rice production in Nigeria. C. I. Alarima, A. Kolawole , C. I. Sodiya , O. I. Oladele , T. Masunaga and T. Wakatsuki. Journal of Food, Agriculture & Environment Vol.9 (3&4): 177-182, 2011 **(Chapter 2).**

2. Knowledge and training needs of farmers adopting sawah rice production technology in Nigeria. C. I. Alarima, A. Kolawole , E. Fabusoro , A. A. Ajulo , T. Masunaga and T. Wakatsuki. Journal of Food, Agriculture & Environment Vol.9 (3&4): 183-188, 2011 **(Chapter 6).**

3. Constraints to Sawah Rice Production System in Nigeria. C. I. Alarima, C. O. Adamu, T. Masunaga and T. Wakatsuki. Journal of Human Ecology, 36(2): 121-130, 2011 **(Chapter 5).**

4. Land Rights and Rental Systems: Implications for Management of Conflicts Related to Land in Sawahbased Rice Production Systems in Nigeria. Cornelius Idowu ALARIMA, Eniola FABUSORO, Ayorinde KOLAWOLE, Kingsley Chinyere UZOMA, Adetayo Kazeem AROMOLARAN, Tsugiyuki MASUNAGA and Toshiyuki WAKATSUKI. African Study Monographs, 33 (3): 189-208, 2012 **(Chapter 4).**

5. Professional Competencies and Training Needs of Extension Agents for Sustainable Sawah Development in Nigeria. Alarima C.I., Fapojuwo O.E., Fabusoro E., Fakoya E.O., Masunaga T., and Wakatsuki T. Journal of EXTENSION SYSTEMS Vol 28 (2) 1-15, 2012 **(Chapter 6).**

6. Determinants of Adoption of Sawah Rice Technology among Farmers in Ashanti Region of Ghana. Cornelius Idowu Alarima, Comfort Oyekale Adamu, Joseph Mubo Awotunde, Mary Nuako Bandoh,Tsugiyuki Masunaga and Toshiyuki Wakatsuki. Journal of Agricultural Science and Technology B 3 (7) 459-468, 2013 **(Chapter 9).**