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

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

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

Abstract

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

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

Introduction

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

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

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

Materials and Methods

Site description

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

Field Development

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

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

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

Laboratory methods

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

Data analysis

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

Results and Discussion

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

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

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

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

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

Table 2: Nutrient compositions (%) in the amendments

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

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

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

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

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

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

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

Other studies elsewhere also uphold the superiority of 'sawah' system over non-'sawah' system especially in terms of nutrient reserve for profitable rice production (Wakatsuki *et al.*, 2002; Ganawa *et al.*, 2003; Wakatsuki and Masunaga, 2005).

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

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

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

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

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

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

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

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

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

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

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

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

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

Conclusion

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

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

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

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

Abstract:

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

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

Introduction

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

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

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

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

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

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

Materials and Methods

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

Determination of Soil Physical Properties

The soil physical parameters determined from soil samples were:

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

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

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

Determination of soil chemical properties

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

Results and Discussion

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

Soil texture

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

Soil chemical properties

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

Soil physical properties

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

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

Sawah Location	Year	pH (H_2O)	OM (%)	TC (g/kg)	TN (g/kg)	C:N ratio	Av. P ($mgkg^{-1}$)	Ex. K ($cmolkg^{-1}$)
Adugyana	2007	5.0	4.1	23.0	2.7	8.5	2.7	0.32
	2008	5.2	4.0	224	2.0	11.2	2.6	0.31
	2009	5.9	3.9	21.8	2.3	9.5	2.4	0.32
Biemso1	2007	5.7	3.3	18.5	1.4	13.2	3.6	0.27
	2008	6.0	3.5	19.6	1.6	12.3	3.5	0.25
	2009	5.0	3.2	17.9	1.6	11.2	3.5	0.26
Kwadaso	2007	4.9	2.2	12.3	1.3	9.5	3.2	0.22
	2008	5.6	2.4	13.4	1.3	10.3	3.2	0.22
	2009	5.6	2.5	14.0	1.4	10.0	3.2	0.23
'Sawah' Mean		5.4	3.2	18.1	1.7	10.6	3.1	0.27
Rain fed Lowland Ecology								
Adugyana	2007	4.8	1.8	10.1	1.6	6.3	9.0	0.16
	2008	4.5	1.6	8.9	1.4	6.4	8.7	0.16
	2009	4.2	1.2	6.7	1.2	5.6	8.7	0.17
Biemso1	2007	5.2	2.1	12.1	1.1	11.0	9.0	0.13
	2008	5.0	1.7	9.5	1.2	7.9	8.8	0.14
	2009	4.8	1.3	7.2	1.2	6.0	8.9	0.14
Kwadaso	2007	4.9	2.6	14.2	1.1	12.9	6.0	0.17
	2008	4.4	2.0	11.2	1.1	10.2	6.1	0.17
	2009	4.4	2.1	11.0	0.9	12.2	6.2	0.18
RLE Mean		4.7	1.8	10.1	1.2	8.4	7.9	0.16
LSD		0.5	0.9	5.1	0.4	2.3	2.7	0.06

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

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

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

VMC- volumetric moisture content of soil

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

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

Rice yield relationship with chemical and physical soil properties.

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

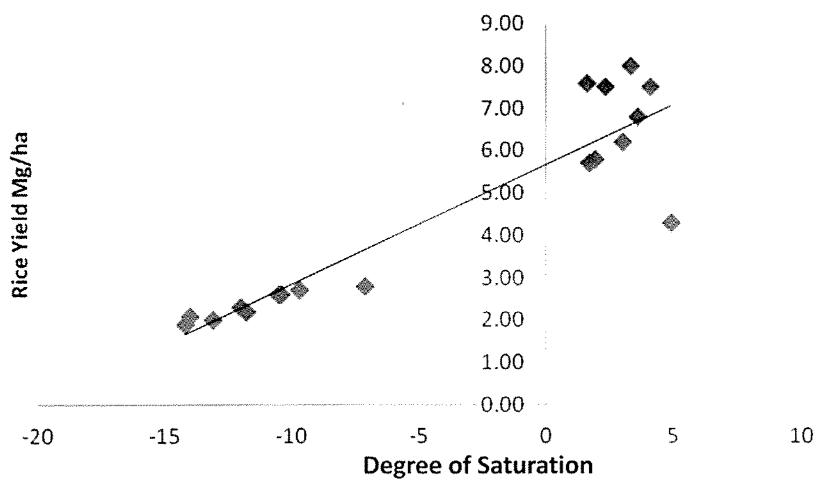

Figure 1: Relationship between soil degree of saturation and rice yield

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

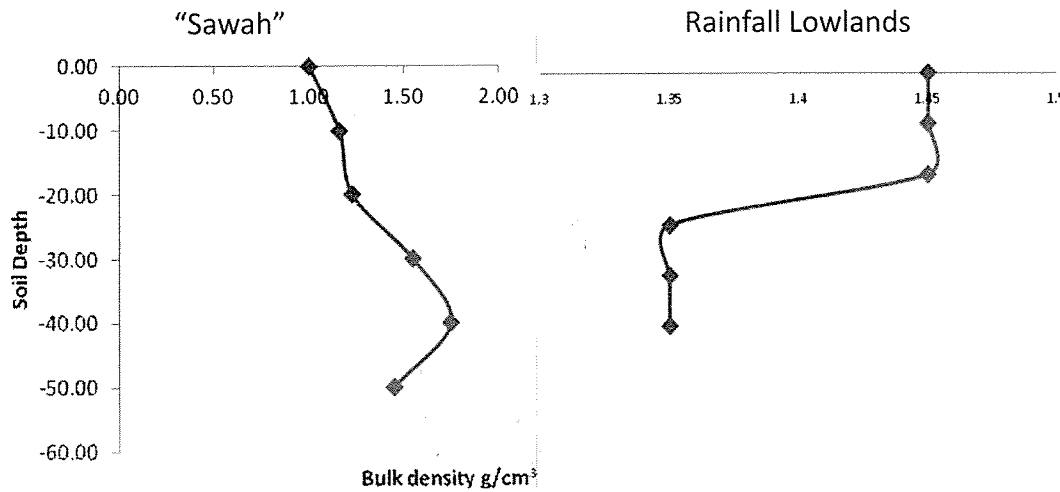

Figure 2: Variation in soil bulk density (soil compaction with depth) for the rice ecologies

Conclusion

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

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

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

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

Abstract

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

Introduction

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

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

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

Rice Ecologies and their Potentials

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

Out of the total land area of 1.64million ha devoted to rice cultivation in Nigeria, 1%, 5%, 16%, 30% and 48% is grown to mangrove swamp, deep water rice, irrigated lowland, rain-fed upland and rain-fed lowland, respectively. In West Africa, however, of the total land area of 4.01million ha devoted to cultivation of rice, 4%, 9%, 12%, 44% and 31% is planted to mangrove swamp, deep water, irrigated lowland, rain-fed upland and rain-fed lowlands respectively Lançon and Erenstein (2002). To increase the production of rice in West Africa therefore there is the need to re-allocate more resources to inland valley which are more productive than dissipating our energies and scare resource on the upland. More importantly, the adoption of simple technology such as 'sawah' that will enhance the productivity of inland valleys should also be accepted if the gap between consumption and production must be closed in West Africa. Asia continent is leading in rice production in the world, probably because, they chose the right combination of ecology and technology. The time has come for farmers in Sub-Sahara Africa to relocate rice production in the upland to more productive lowland ecology using the 'sawah' rice production technology.

Sustainable 'sawah' rice production systems

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

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

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

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

Experiences in Abeokuta 'sawah' rice production systems

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

'Sawah' rice field experience in 2011

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

Problems arising from leakages

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

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

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

Lack of funding

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

Poor post harvest facilities and poor marketing structures.

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

The role of government policies

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

Conclusion

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

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

Joshua Aliyu and Baba Taitus

Abstract

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

Introduction:

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

Derived processes and procedures

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

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

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

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

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

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

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

The regular visits can be good, coupled with good knowledge about *Sawah* rice farming, but if there is not enough energy to relay such information for farmers to understand, it may not create interest in the farmer to stick to *Sawah*. It is therefore proper to learn the art of relaying information to farmers, so that they can easily understand and get convinced to accept appropriate actions. Hence there is need to have verbal coherent ability for message delivery.

(iv). *Clarify work division issues before commencement of work.*

When a farmer indicates his interest in *Sawah*, we need to iron out issues before any commencement of work. This program, no doubt, is of a farmer participatory approach. In terms of roles to be played, each has functions to perform. These functions need to be well clarified before work starts. We must not allow work to be progress or about to end, before we begin talk of vital things that needed to be discussed at the beginning. This can cause friction, or retard progress of work. An example could be on transplanting. If a farmer is not aware of doing the work from start to finish of this activity, he/she may think that it is the duty of the project or extension officer.

(v). Solve farmers problems

It is certain that problems will emanate. When problems crop up in the field in terms of pests, disease or machinery, try to assist in solving them immediately. Delays or not showing much concern is not good. Other problems may come up which may not be associated with '*Sawah*'. Farmers see you as their welfare officer. Try to assist them even though it may not be direct. Help by getting them to people, places where they could get assistance but remember not to make promises that you cannot fulfil.

(vi). Maintain cordial relationship with farmer.

A good cordial relationship with farmers is also a very important factor for '*Sawah*' development implementation. Farmers may not develop good understanding and interest for 'Sawah', if working relationship is sagged. Excessive quarrels and dabbling into village issues should be avoided. Note that your major task in these villages is to extend 'Sawah' technology. Pay homage to the village head or community leader intermittently. When you have problems or need any assistance, let them know.

(vii). Never quit when your first attempt fails.

If in your first operation, you are not able to get good result, don't quit as quitting is dangerous. Always observe critically to know the reasons for failure and surely you will get reasons. Make your reasons known to the farmer in a way he would understand, and encourage him to make another try. When farmers get to know the causes of some problems, they easily understand and don't get discouraged. However, when no reasons are identified to show for some poor results, farmers may find it difficult to continue. Concentrate on areas where farmers need advice. During field observations, always hammer on areas where farmers need advise for corrections or amendments.

(viii). Never hide results of rice yields

Results from 'Sawah' fields are always encouraging. At the end of harvest, transfer information to other villages, particularly to communities where *sawah* has not yet reached. Encourage farmers to visit 'Sawah' fields on their own and when coincidentally we meet them in the field, we should explain to them on how we have arrived at that standard. Use correct tools and materials to ease work on the field.

(b). Problems Encountered and Solutions

'Sawah' development is not without problems. Problems can be from extension staff, farmers or the natural environment. Problems that we do observe are location Specific. Hence they are treated under the various locations.

BIDA (Niger State):
Problems encountered include: (i) Lack of interest, (ii) fear of Government taking over land, (iii) capital and (iv) land degradation.

Solutions provided included education. Lack of interest by some farmers was common at the inception of the programme. However, through education this is not very common now. From time to time farmers are educated on the effect of *Sawah* as a food producing venture which has positive advantage on the totality of their livelihood. Nevertheless, we don't tie ourselves to them permanently trying to encourage them. We move ahead to see those who can take the technology for us to work with because when we make progress, those who showed no interest would get to hear and would follow suit. Through this the percentage of farmers who show no interest is reduced drastically. At the inception of *Sawah*, fear gripped most farmers because they taught of it as a plan by Government to take over their rice fields. Indeed, we had to talk intensively and extensively with ward, village, community heads as well as farmers that their thinking was wrong and that the information was not true. However since then, no single farmer's field had been taken from him/her. Farmers thought that unless you had much capital 'Sawah' was not easy to develop. What we thought them was to redeem small portions of their fields to '*Sawah*' annually, so that they will not have to spend much money at a time. This solved the problem of capital. Within periods their whole field were developed into '*Sawah*'. Hence a farmer can put his whole farm into 'Sawah' within a given time frame.

Land developed into *Sawah* fields becomes degraded. Another problem we encountered was farmer's perception that if a power tiller puddles a field, the result will be erosion leading to degradation of land. We take such farmers to most fields where '*Sawah*' has been in practice and when they fail to see any degraded lands due to 'Sawah'activity, they immediately become convinced.

ZARIA - Kaduna State (UNDP Millennium Villages)
Problem encountered was crop yield failures in 2007 and 2008, when rice variety Wita 4 (Faro 52) a long duration variety was used.

Solution:
It was realized that this place is in northern Nigeria that witness short rainfall and that the rice variety used could not be grown because of its duration. While in 2007,

the crop had very good vegetative growth but unable to mature due to water shortage with a total failure, in 2008, 20% loss was observed. The solution provided was to introduce a short duration hybrid variety-Faro 44 (CP). Since 2009 harvest has been good. The yield for 2011 has been the best so far.

KEBBI State (North West Nigeria)
Problems encountered were (i) improper management of farmer-groups operations and (ii) unmastery skills in power tiller handling.

Solution provided was basically training. Time was set aside and farmers trained on how to manage groups. Farmers are therefore becoming perfected. The 'Sawah' demonstration just got to this place this year (2011). Therefore it is expected that operators will have to work for sometime during the coming year (2012) before they can attain some level of perfection.

Work Scope and Success
Indeed work scope in terms of site coverage as mention earlier can be put at 25 - 30 villages and towns. On area coverage it can be put at 100 ha. On yield, we have recorded yields not by extrapulation but physical pa%y production of 4.27t ha^{-1}, 5.67t ha^{-1} and 7.27t ha^{-1} respectively across locations.

Comments on Farmers.
Farmers love to associate with something that could increase their crop yields for the betterment of their livelihood, and this should be the 'Sawah' Technology. Farmers are not difficult in accepting technologies as they are normally perceived. Unclear messages can scare farmers. Farmers now see the sawah system as simple, unchaic, and practicable. My recommendation is that extension should be more upright in the approach to farmers. Farmers are our best friends and so we need to avoid doing things that will put extension on a collision course with them.

Conclusion
We have tried to put our experiences into this report hoping that even if some were left out it will not be much. Since a '*Sawah*' operational guide booklet will be published, I have tried to avoid listing all the '*Sawah*' operations. On success, extension has already gotten off to some appreciable footing. I therefore see no reason why we cannot cover effectively the areas intended to be covered in the nearest future in Nigerian.