Asian Journal of Agriculture and Food Sciences (ISSN: 2321 – 1571)
Volume 01– Issue 03, August 2013

Evaluation of Water Sources for Sawah Management in the Restoration of Degraded Lowlands and Sustainable Rice Production in Southeastern Nigeria

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ABSTRACT— ***Agricultural productivity in Nigeria fluctuates, mainly because the country's agriculture is rain-fed and subsistence farmers rely on the rain as the main backbone of farming in the country. Consequently, traditional water management systems in the lowlands rice production in Ebonyi State that is regarded as a major rice producing State in Nigeria who also rely on the rain, are characterized by the fact that farmers focus on storage of water in the rice field, without any possibility to divert water from one place to another. In an attempt to arrest the declining productivity of the inland valley soils in these zones due to poor water control and fertility management, four different organic sources, including the control (Rice husk; Rice husk ash; Poultry droppings at 10 t/ha and NPK 20:10:10 at 400 kg/ha and 0 t ha^{-1}) were used in three different water sources (sawah types) (rain-fed, pump-fed and spring-fed sawah) in two inland valleys in southeastern Nigeria to evaluate their effects on some soil properties and rice grain yield. Sawah is generally described as a controlled water management in the field where the soil is expected to be puddle, leveled and bunded in order to impound water provided by rain water or by rise in the level of a river in an inland valley. A split- plot in a randomized complete block design was used to asses the two factors at different levels. Three sources of water (sawah types); rain-fed sawah, spring type and pump type constituted main plot, while the amendments, that constituted the sub- plots were applied as follows: 10 tha^{-1} rice husk (RH); 10 tha^{-1} of rice husk ash; 10 tha^{-1} of poultry droppings; 400 kgha^{-1} of N.P.K. 20:10:10 and 0 tha^{-1} (control). The treatments were replicated three times in each of the subplots. The results of the study showed that the soil pH was significantly improved by different water types in the two locations. As the pH was improved statistically upon by different soil amendments in the two sites, the interaction of water sources and amendments only significantly improved the pH in Ikwo location. The results also indicated that soil organic carbon and total nitrogen were positively influenced in the two locations by both the different water sources and amendments. The result shows a significant improvement on the CEC by both factors in Ikwo site. It was also recorded that available phosphorous were positively improved by different water sources and amendments in different forms in the two locations. The result equally indicated that rice grain yiled was positvely increased in both locations by the studied factors.***

Key words: *sawah*, amendments, rice grain yield, soil properties, inland valleys

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1. INTRODUCTION

Agricultural productivity in Nigeria fluctuates, mainly because the country's agriculture is rain-fed and subsistence farmers rely on the rain for farming activities in the country. Rain fed agriculture is an important economic activity in the developing world. Globally, rain fed agriculture is practiced in 80% of the total physical agricultural area and generated 62 percent of the world's staple food [1, 2]. In sub-Saharan Africa, 93 percent of cultivated land is rain fed [3], thus playing a crucial role in food security and water availability [4]. Kadigi *et al*. [5] argues that land for rain-fed agriculture varies depending on the amount and distribution of rainfall in the area. Yields from rain-fed agriculture are often low, generally around 1 t ha^{-1} in semiarid tropical agroecosystems [6]. There is ample evidence to suggest that the low productivity in rain-fed agriculture is due more to suboptimal performance related to management aspects rather than to low physical potential [7, 8, 9, 10]. This means that in the developing countries with the most rapid population growth, dependence on rain-fed agriculture operating at suboptimal level is high. Gowing *et al.* [11] maintained that inadequate soil moisture and low soil fertility have been top challenges facing rainfed agriculture. To narrow the yield gap in rainfed lowlands environments, improvement of farm infrastructures such as land leveling, irrigation and drainage facilities modifications should be done. Supplementary irrigation is needed when natural precipitation is not adequate to secure grain and forage production [12]. Nigeria is relatively blessed with rain and high potential of inland valleys. The major constraints in the utilization of these inland valleys for sustainable rice based cropping include, poor soil fertility maintenance, inadequate weed and water control [13, 14, 15, 16]. Studies on the interaction of organic and inorganic manure with water management systems to improve soil properties under rice *sawah* management system have not received much attention in Nigeria.

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 [17, 18]. *Sawah* refers to leveled rice field surrounded by bunds with inlets and outlets for irrigation and drainage. *Sawah* system ensures that certain water level (minimum and maximium) is maintained in field plots during the growing period of the plant. It restores/replenishes the lowland with nutrients as it resists erosion. The mechanisms in *sawah* system of nutrient replenishments encourage not only rice growth, but also the breeding of various microbes, which improves biological nitrogen fixation.

The objectives of study include, to determine changes in soil characteristics and crop yield due to pump, rain-fed and spring *sawah* types, evaluate the contributions of different manure types to changes in soil properties and grain yield, and determine the interactions of different irrigation types and soil amendments on soil properties and rice grain yield.

2. MATERIALS AND METHODS

2.1 Description of Sites, Experimental Design and Soil Sampling

This study was conducted in inland valley at two different locations (Akaeze and Igweledoha-Ikwo) in 2011 cropping season to evaluate the effects of different sources of water for *sawah* water management system and amendments on soil properties and rice grain yield. Akaeze lies at approximately latitude $05^0 55'$ N and longitude $07^0 40'$ E. the annual rainfall for the is 1,350 mm, spread from April to October with average air temperature of 29^o C. Igweledoha-Ikwo on the other hand, lies within latitude $06^0 04'$ N and longitude $08^0 16'$ E. The major geological material for the two soils is shale from the Asu River formation. Mean annual rainfall (precipitation) is 1800 mm for Akaeze and 1600 mm for Ikwo. Rainfall is usually spread between April and October. Average temperature for the area is 29^0 C with a very insignificant difference between the rainy and dry season [19].

In each of the two locations (Akaeze and Ikwo), soil amendment trials were. The two sites are within the derived savanna vegetation zone with grassland and tree combinations. The soils are described as Aeric Tropoaquent [20] or Gleyic Cambisol [21]. The soils have moderate soil organic carbon (OC) content on the topsoil, low in pH and low cation exchange capacity (CEC). Soils are mainly used for rain-fed rice cultivation during the rains and vegetable production as the rain recedes.

2.1.1 Field Method

The field in each location was divided into three different main plots where the three sources of water for irrigation (*sawah* types) were located. Bulk (composite) sample was collected at 0- 20 cm soil depth in the 2 locations for initial soil characteristics. The three main plots were demarcated into five subplots with a 0.6 m raised bunds where the soil amendments were applied.

A split- plot in a randomized complete block design was used to asses the two factors at different levels. The three sources of water (*sawah* types) that constituted main plot include;

- rain-fed *sawah* which involved plots where water supply was only from rain water and no irrigation water was allowed to flow into the plots.
- spring type, on its own was where water source was from a spring that flows into the field and perhaps rainfall with some control, and
- pump type involved water application to plots as supplemental irrigation with pumping machine from an artificial pond in the field.

Generally, Water was circulated in the field by manipulation of the bunds. The water flows from the spring to the plots through a constructed canal from the spring source to the field and the spring is close-by to the field, less than 100 m away. The quantity of water issued to the plots was not measured rather the depth of water was maintained at 5 cm- 10 cm throughout the growing period of the rice except in the rain-fed plots where only the water harvested by each plot during rainfall that settle in the plots. Ruled sticks with bold marks on 10 cm and 5 cm points were mounted permanently on each plot to check the water level or depth in the field. In the pumping type a pumping machine with rated power output of 2.8 kilowatts, self priming volute with 4 impeller blades and maximum discharge of 900 litres/minute, plus a total Head of 26 M, was used to pump water from an artificial pond into the field receiving pumping water as a supplemental irrigation, whenever water depth in the plots is below 5 cm. The water introduction in each case was made 2 weeks after transplanting and this was maintained till the stage of ripening of the rice grains. The water from these different sources in the field is presumed to have different qualities and as such would have different effect on the soil properties and rice yield.

The amendments, that constituted the sub- plots were applied as follows:

- PD Poultry droppings @ 10 ton/ha
- F NPK fertilizer (20:10:10) @ 400 kg/ha recommended rate for rice in the zone
- RH Rice husk @ 10 t ha^{-1};
- RHA Rice husk ash @ 10 t ha^{-1}
- CT Control @ 0 t ha^{-1}

The treatments were replicated three times in each of the subplots. 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 high-tillering rice variety *Oryza sativa var. FARO 52 (WITA 4)*. The rice seeds were first raised in the nursery and later transplanted to the main 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.

2.1.2 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 [22]. Soil pH was measured in a 1:2.5 soil:0.1 M KCl suspensions [23]. The soil OC was determined by the Walkley and Black method described by Nelson and Sommers [24]. Total nitrogen was determined by semi-micro kjeldahl digestion method using sulphuric acid and $CuSO_4$ and Na_2SO_4 catalyst mixture [25]. CEC was determined by the method described by Thomas, [26]. The available phosphorous was determined by the Bray 11 method [27].

2.1.3 Data Analysis

Data analysis was performed using **GENSTAT** 3 7.2 Edition.
Significant treatment means was separated and compared using Least Significant Difference (LSD) and all inferences were made at 1% and 5% Levels of probability.

3 RESULTS AND DISCUSSION

3.1 Soil Properties, Organic Amendments and Water Properties

3.1.1 Soil properties

The prominent soil physical and chemical properties are reported in Table 1. Generally, the soils from the two locations are sandy loam with 100-160 g kg^{-1} clay and 130-150 g kg^{-1} silt content. Clay content was higher in Ikwo location than in Akaeze site. Bulk density values of the soils varied from 1.45 to 1.50 Mg cm^{-3} while mean-weight diameters of the soil aggregates were between 1.09 to 1.30 mm.

The soil texture is coarse to medium with high soil bulk density (1.6-1.9 g cm^{-3}) and low soil porosity [28]. Soil inventory of the high rainfall region of southeastern Nigeria show that the major soil unit consists of deep, course textured, well-drained acidic sandy loam, largely derived from coastal plain sand sediments, sandstones and shales. The dominant soil has been classified as kaolinitic utisols belonging to the soil taxonomy of Typic Paleudult [29]. According to Ezemonye and Emeribe [30], the soils of the study area were derived from shale and sandstone parent materials. These soils are generally deep, porous and acidic. Agricultural land use still is a major occupation for more than 60 percent of the populace of the study area.

Soil organic carbon concentration was higher in Ikwo site (13.00 g kg^{-1}) than at Akaeze (11.80 g kg^{-1}) location, whereas the soil total nitrogen was higher at Akaeze site. pH measured in water was higher in Akaeze soils than at Ikwo location. The analysis indicated that the two soils were low in exchangeable bases. Also, the CEC was moderate in both locations.

3.1.2 Organic amendments properties

Rice husk amendment had the highest percentage organic carbon, followed by rice husk ash, while poultry dropping recorded the least value. This means that rice husk has the potentials of enriching the soil more with organic carbon pools. The analysis also indicated that total nitrogen was higher in poultry dropping, while the least TN was recorded in rice husk ash. The analysis (Table 2) showed that rice husk ash gave the highest values for percentage potassium and magnesium, while the highest percentage calcium was obtained from poultry dropping.

3.1.3 Water properties

The water analysis (Table 3) showed that the pH of water studied varied from 6.0 to 6.6, with spring water having the highest pH value. The electrical conductivity value was higher in pumping water source. The water analysis also indicated that the values of heavy metals such as boron and manganese were higher in spring water source, while zinc and iron were lower in field plots treated with rain-fed water in Ikwo location. Plots treated with spring water had lower boron and zinc contents.

Table 1. General description of soil characteristics of the studied area before puddling and amendments

Soil Property	Akaeze	Ikwo
Clay (g kg^{-1})	100	160
Silt (g kg^{-1})	150	130
Sand (g kg^{-1})	750	710
Textural class	Sandy loam	Sandy loam
Bulk density (Mg m^{-3})	1.50	1.45
Mean-weight diameter (MWD) (mm)	1.30	1.09
OC (g kg^{-1})	11.80	13.00
TN (g kg^{-1})	1.00	0.90
pH (H_2O)	4.50	4.30
Na^+ ($cmol_c$ kg^{-1})	0.03	0.03
K^+ ($cmol_c$ kg^{-1})	0.05	0.04
Ca^{2+} ($cmol_c$ kg^{-1})	0.80	0.90
Mg^{2+} ($cmol_c$ kg^{-1})	0.96	0.76
CEC ($cmol_c$ kg^{-1})	8.50	9.86

OC= organic carbon; TN= total nitrogen; K^+= exchangeable potassium; Ca^{2+}= exchangeable calcium; Mg^{2+} = exchangeable magnesium; CEC= cation exchange capacity

Table 2. Properties of the organic amendments

Amendment	OC	Total N	K	Ca	Mg	P	C:N
		(%)					
PD	16.50	2.10	0.48	14.40	1.20	2.55	7.86
RH	33.70	0.70	0.11	0.36	0.38	0.49	48.14
RHA	23.90	0.06	0.65	1.00	1.40	11.94	398.33

PD= poultry droppings; RH= rice husk powder; RHA= rice husk burnt ash; OC= organic carbon.

Table 3. Water analysis results from *sawah* water source for Akaeze and Ikwo locations

Sample description	pH	Electrical conductivity (EC) (mSm^{-1})	Boron -B (ppm)	Iron - Fe (mg/l)	Manganese – Mn (mg/l)	Zinc – Zn (mg/l)
Akaeze Location						
Spring water source	6.0	7	4.75	2.80	32.96	55.57
Pumping water source	6.4	8	3.56	1.96	27.47	53.30
Rain-fed Field water	6.6	6	2.38	2.24	30.22	46.50
Ikwo location						
Spring water source	6.6	3	2.38	2.80	29.98	58.85
Pumping water source	6.1	4	3.56	3.08	29.98	68.65
Rain-fed Field water	6.2	7	3.56	1.12	24.72	42.50

3.2 Effects of Water Sources and Amendments on the Soil pH and Organic Carbon

The results (Table 4) showed that the soil pH measured in water in both locations was significantly ($p < 0.05$) improved by *sawah* types within the period of study with spring *sawah* type giving the best improvement on the soil pH, while rain-fed *sawah* type had the least values. Generally, the result disagrees with the findings of Takase *et al.* [31] who compared river, canal, tap and well irrigation sources in Ghana and found that though none of these *sawah* water types gave significantly higher pH than others, soils irrigated with well water recorded the highest pH value at the end of three months of their study.

The results (Table 4) also showed that soil amendments significantly ($p < 0.05$) increased the soil pH in both Akaeze and Ikwo locations. It was obtained that the soil pH ranged statistically from 3.58 to 4.84 in Akaeze site with rice husk ash (RHA) giving the highest significant ($p < 0.05$) pH improved level in the soil, whereas the control gave the least value. In Ikwo site, the pH values varied from 4.19 to 5.28 with the same rice husk ash giving the highest values. This was followed by poultry dropping (5.01), while the control had the least values. The significant improvement made by RHA on pH agrees with the findings of Abyhammer *et al.* [32]; Markikainen, [33] and Nwite *et al.* [34]; who stated that ash amendment could induce a pH increase by as much as 0.6 – 1.0 units in humus soils. Generally, the result showed that soils treated with amendments increased pH significantly higher than untreated soils in both locations. This is in conformity with the findings of Opara-Nnadi *et al.* [35] who reported pH increase following the application of organic wastes.

The interactions of *sawah* types and amendments significantly ($p < 0.05$) improved pH in Ikwo, but did not increase the pH level statistically in Akaeze location.

It was shown (Table 5) that higher soil organic carbon pool was obtained from Akaeze site than Ikwo site; therefore, soil organic carbon concentration level is dependent upon the location and soil. Perhaps this could be primarily due to differences in the inherent soil characteristics such as particle size distribution and the prevailing climatic conditions within the specific locations as such differences could influence the rate of re-aggregation of the structure after puddling, and alternate wetting and drying. Akaeze has lower clay content but receives higher annual rainfall than Ikwo [19]. Follet [36] showed that sequestering CO_2 from the atmosphere through improved soil management practices can have a positive impact on soil resources, because increasing soil C increases the functional capabilities of soils. It was also obtained from the results that soil amendments significantly improved the soil organic carbon relatively higher than the control in the two locations. The result equally indicated a significantly higher SOC pool in plots amended with rice husk dust than plots amended with other treatments. This result did not conforms with the findings of Igwe *et al.* [19] who reported that at Ikwo location, apart from NPK and RHA-amended plots, there was no improvement in SOC of the whole soils; and in Akaeze soils, the treatments improved SOC in the whole soils except in the soils amended with poultry dropping (PD). The result confirms the findings of Lee *et al.* [37] who reported from a long-term paddy study in southeast Korea that continuous application of compost improved SOC concentration and soil physical properties in the plough layer, relative to inorganic fertilizer application. The results also showed a significant improvement on the SOC buildup with the interaction of *sawah* types and amendments in Akaeze site. This agreed with the submission that incorporation of plant residues coupled with appropriate puddling and water management build up organic carbon status of soil [38].

Table 4: Effects of water sources and amendments soil pH (0 – 20 cm) soil depth

Water source	Amendments					
	CT	NPK	PD	RH	RHA	Mean
Akaeze						
Pumping	3.53	4.40	4.70	4.43	4.80	**4.37**
Rained	3.47	4.50	4.50	4.50	4.60	**4.31**
Spring	3.73	4.80	4.80	4.73	5.13	**4.64**
Mean	**3.58**	**4.57**	**4.67**	**4.56**	**4.84**	
LSD (0.05) Water source			0.111			
LSD (0.05) Amendment			0.141			
LSD (0.05) Water source x Amendment				NS		
Ikwo						
Pumping	4.17	4.97	5.10	4.90	5.27	**4.88**
Rained	3.93	4.73	4.83	4.73	5.00	**4.65**
Spring	4.47	4.97	5.10	4.97	5.57	**5.01**
Mean	**4.19**	**4.89**	**5.01**	**4.87**	**5.28**	
LSD (0.05) Water source				0.069		
LSD (0.05) Amendment				0.080		
LSD (0.05) Water source x Amendment				0.133		

CT = control, NPK = nitrogen. phosphorous. potassium, PD = poultry dropping, RH = rice husk, RHA = rice husk ash.

Table 5: Effects of water sources and amendments soil organic carbon (0 – 20 cm) soil depth

Water Source	Amendments					
	CT	NPK	PD	RH	RHA	Mean
Akaeze						
Pumping	0.803	1.470	1.313	1.640	1.027	**1.251**
Rained	0.850	1.350	1.240	1.357	1.260	**1.211**
Spring	0.990	1.813	1.460	1.887	1.200	**1.470**
Mean	**0.881**	**1.544**	**1.338**	**1.628**	**1.162**	
LSD (0.05) Water source				0.1864		
LSD (0.05) Amendment				0.1372		
LSD (0.05) Water source x Amendment				0.2540		
Ikwo						
Pumping	0.687	1.147	1.237	1.400	1.127	**1.119**
Rained	0.707	1.020	1.047	1.230	1.040	**1.009**
Spring	0.993	1.383	1.443	1.477	1.230	**1.305**
Mean	**0.796**	**1.183**	**1.242**	**1.369**	**1.132**	
LSD (0.05) Water source				0.0992		
LSD (0.05) Amendment				0.1124		
LSD (0.05) Water source x Amendment				NS		

CT = control, NPK = nitrogen. phosphorous. potassium, PD = poultry dropping, RH = rice husk, RHA = rice husk ash, NS = Not significant.

3.3 Effects of Water Sources and Amendments on the Soil Total Nitrogen

The soil total nitrogen was found to have been significantly ($p < 0.05$) influenced by *sawah* types in both locations (Table 6). It was obtained that in both Akaeze and Ikwo sites, spring *sawah* type (0.095 and 0.109%), respectively, relatively improved the soil total nitrogen higher than pumping and rain-fed *sawah* types. The result agrees with the findings of Kyuma and Wakatsuki, [39] and Greenland, [40] that the amount of nitrogen fixed by microbes varies from 20 to 100 kg ha–1 year–1, and sometimes reaches up to 200 kg ha–1 year–1, depending on soil and water management and climatic conditions [39, 40]. The low percent of soil total nitrogen concentration in rain-fed *sawah* treated soils agrees with the findings of Gowing *et al.* [11]; Barron *et al.* [41]; Quinn *et al.* [42]; Mupangwa *et al.* [43]; Makurira *et al.* [44] who maintained that inadequate soil moisture and low soil fertility have been top challenges facing rain-fed agriculture.

The results (Table 6) equally pointed highly significant differences on the soil total nitrogen with application of amendments in the two locations. The result indicates that poultry dropping (0.105 and 0.114%) in Akaeze and Ikwo sites, respectively, performed statistically ($p < 0.05$) better in both locations. This result confirms the submissions of Imolehin and Wada [45] who advocated a reversion to the use of organic materials in wetland rice cultivation as a more realistic option for farmers than continued reliance on inorganic fertilizers, which in addition to their deleterious effects on the soil are not readily available.

There was no significant improvement on the soil total nitrogen by the interaction of *sawah* types and amendments in both locations.

Table 6: Effects of water sources and amendments soil total nitrogen (0 – 20 cm) soil depth

Water Source	**Amendments**					
	CT	**NPK**	**PD**	**RH**	**RHA**	**Mean**
Akaeze						
Pumping	0.06300	0.09533	0.10333	0.08433	0.08733	**0.08667**
Rained	0.04800	0.09400	0.09500	0.09000	0.08200	**0.08180**
Spring	0.06000	0.10300	0.11667	0.10267	0.09467	**0.09540**
Mean	**0.05700**	**0.09744**	**0.10500**	**0.09233**	**0.08800**	
LSD (0.05) Water source				0.00612		
LSD (0.05) Amendment				0.00622		
LSD (0.05) Water source x Amendment				NS		
CV% source				3.1		
Ikwo						
Pumping	0.0607	0.1037	0.1087	0.0997	0.0947	**0.0935**
Rained	0.0693	0.0987	0.1027	0.1043	0.0840	**0.0918**
Spring	0.0713	0.1163	0.1293	0.1140	0.1113	**0.1085**
Mean	**0.0671**	**0.1062**	**0.1136**	**0.1060**	**0.0967**	
LSD (0.05) Water source				0.01169		
LSD (0.05) Amendment				0.01348		
LSD (0.05) Water source x Amendment				NS		
CV% source				5.3		

CT = control, NPK = nitrogen. phosphorous. potassium, PD = poultry dropping, RH = rice husk, RHA = rice husk ash.
NS = Not significant

3.4 Effects of Water Sources and Amendments on the Soil Cation Exchange Capacity

The results (Table 7) showed that while there was no statistical variation on the soil cation exchange capapcity (CEC) among the *sawah* types and amendments in Akaeze location, Ikwo site significantly ($p < 0.05$) improved the CEC. Spring *sawah* type (14.20 $cmolkg^{-1}$) was generally observed to have significantly ($p < 0.05$) influenced the CEC higher relative to the rain-fed *sawah* type (12.51 $cmolkg^{-1}$) in Ikwo site. This level of improvement could be attributed to ideal land use patterns and landscape management practices which optimized the geological fertilization processes through the optimum control of hydrology in a given watershed [46]. The results also agreed with Eswaran *et al.* [47] and Abe *et al.* [46], that surface and sub-surface water increase the supply of nutrients, such as Si, Ca, Mg, K and sulfate and these natural soil fertility replenishment mechanisms are essential for enhancing the sustainability and productivity of lowland rice farming systems in inherently unfertile soils in West Africa and Sub-Saharan Africa.

Table 7 also indicated a significant ($p < 0.05$) improvement on the soil CEC due to amendments within the period of study in Ikwo location. Poultry dropping amendment generally improved the soil CEC higher than other amendments in the soil. It was also observed generally that soil CEC was better improved on Ikwo soils than Akaeze soils. This could be attributed to higher silt and clay content in Ikwo site with higher surface area that encourages expansion, hence, increase in nutrients and water absorption. This is in line with the findings of Igwe *et al.* [19] in an experiment conducted in the same locations that MWD of these puddled soils was higher at Akaeze than at Ikwo probably because of the higher clay content at the latter.

Table 7: Effects of water sources and amendments soil CEC (0 – 20 cm) soil depth

Water Source	Amendments					
	CT	NPK	PD	RH	RHA	Mean
Akaeze						
Pumping	3.8	7.9	9.7	9.5	41.0	**14.4**
Rained	3.9	7.7	8.9	8.4	8.1	**7.4**
Spring	4.6	10.3	11.5	13.1	12.1	**10.3**
Mean	**4.1**	**8.6**	**10.0**	**10.3**	**20.4**	
LSD (0.05) Water source				NS		
LSD (0.05) Amendment				NS		
LSD (0.05) Water source x Amendment				NS		
CV% source				57.5		
Ikwo						
Pumping	8.53	13.53	15.27	13.33	14.47	**13.03**
Rained	8.40	12.33	14.53	12.67	14.60	**12.51**
Spring	9.40	14.20	16.13	14.87	16.40	**14.20**
Mean	**8.78**	**13.36**	**15.31**	**13.62**	**15.16**	
LSD (0.05) Water source				0.988		
LSD (0.05) Amendment				0.858		
LSD (0.05) Water source x Amendment				NS		
CV% source				3.3		

CT = control, NPK = nitrogen. phosphorous. potassium, PD = poultry dropping, RH = rice husk, RHA = rice husk ash.
NS = Not significant

3.5 Effects of Water Sources and Amendments on the Soil Available Phosphorous

It was generally observed that *sawah* types did give statistical ($P< 0.05$) influence on the available phosphorous in in both locations. The result (Table 8) indicated that spring *sawah* type (9.83 and 9.68 mg/kg) in both Akaeze and Ikwo, respectively, highly significantly ($P< 0.05$) improved the Avail. P more than other *sawah* types.

Tables 8 shows that soil amendments significantly increased the available phosphorous within the period of study in both locations. It was also obtained that in Akaeze location, RHA (11.08 mg/kg) did increase the available phosphorous statistically higher in all the soils within,while in Ikwo location, the highest significant mean value for available phosphorous was obtained from plots amended with PD (9.48 mg/kg)

Table 8: Effects of water sources and amendments soil available phosphorous (0 – 20 cm) soil depth

Water Source	Amendments					
	CT	NPK	PD	RH	RHA	Mean
Akaeze						
Pumping	3.56	8.51	8.48	9.54	10.01	**8.02**
Rained	3.78	4.97	7.57	6.23	7.97	**6.10**
Spring	4.42	10.56	8.30	10.58	15.26	**9.83**
Mean	**3.92**	**8.01**	**8.12**	**8.79**	**11.08**	
LSD (0.05) Water source				2.090		
LSD (0.05) Amendment				2.155		
LSD (0.05) Water source x Amendment				NS		
CV%				11.6		
Ikwo						
Pumping	5.29	9.71	8.98	8.91	7.44	**8.07**
Rained	5.01	6.90	8.19	7.36	7.19	**6.93**
Spring	6.11	11.51	11.27	9.23	10.31	**9.68**
Mean	**5.47**	**9.38**	**9.48**	**8.50**	**8.31**	
LSD (0.05) Water source				1.959		
LSD (0.05) Amendment				1.299		
LSD (0.05) Water source x Amendment				NS		
CV%				10.5		

CT = control, NPK = nitrogen. phosphorous. potassium, PD = poultry dropping, RH = rice husk, RHA = rice husk ash.
NS = Not significant.

3.6 Effects of Water Sources and Amendments on Rice Grain Yield (t ha^{-1})

The results (Table 9) showed that different *sawah* water types significantly ($p < 0.05$) increased the rice grain yield in locations. The mean grain yield values ranged from 5.36 – 6.96 t ha^{-1} in Akaeze and 4.75 – 6.13 t ha^{-1} in Ikwo site with spring *sawah* types increasingly improved the grain yield higher than the other two *sawah* types. This results agreed with the submission that the *sawah* system is the only practical option that allows rice farmers to enjoy optimal water management in their fields. Improved performance of field water management can sustainably increase rice yields [48, 49, 50].

The least yield obtained from rain-fed treated plots is an ample evidence to suggest that low productivity in rain-fed agriculture is due more to suboptimal performance related to management aspects rather than to low physical potential [7, 8, 9, 10].
The results indicated very great significant ($p < 0.05$) improvements in the yield of rice in the amended plots over the non-amended (control) plots in both (Table 9). It was generally observed that plots amended with poultry dropping (6.96 and 7.66 t ha^{-1}) greatly significantly ($P < 0.05$) increased the grain yield higher in both Akaeze and Ikwo locations, respectively.

Table 9: Effects of water sources and amendments on rice grain yield (t ha^{-1})

Water Source	Amendments					
	CT	**NPK**	**PD**	**RH**	**RHA**	**Mean**
Akaeze						
Pumping	3.93	7.01	6.17	6.66	6.45	**6.04**
Rained	2.60	6.31	6.45	4.98	6.45	**5.36**
Spring	4.21	7.30	8.27	7.22	7.78	**6.96**
Mean	**3.58**	**6.87**	**6.96**	**6.29**	**6.89**	
LSD (0.05) Water source				1.081		
LSD (0.05) Amendment				0.809		
LSD (0.05) Water source x Amendment				NS		
CV%				7.8		
Ikwo						
Pumping	2.10	5.30	5.73	5.43	5.20	**4.75**
Rained	1.97	6.30	7.80	8.00	6.57	**6.13**
Spring	2.53	6.90	9.43	7.83	6.83	**6.71**
Mean	**2.20**	**6.17**	**7.66**	**7.09**	**6.20**	
LSD (0.05) Water source				1.235		
LSD (0.05) Amendment				0.985		
LSD (0.05) Water source x Amendment				NS		
CV%				9.3		

CT = control, NPK = nitrogen. phosphorous. potassium, PD = poultry dropping, RH = rice husk, RHA = rice husk ash.
NS = Not significant

4 CONCLUSIONS

The study revealed the superiority of spring *sawah* water source over other *sawah* types as it aids in full realization of the geological fertilization process that do occur in inland valley *sawah* system. It was noted the superiority of organic amendments over mineral fertilizer in soil properties and grain yield improvement. It was equally obtained that the combination of good *sawah* management and amendment practices will improve the soil properties and rice grain yield. Therefore, s*awah* eco-technology is possibly the most promising rice production method and restoration of degraded inland valley soils in the Southeastern Nigeria because the *sawah* system is already a highly productive and sustainable rice production system. The natural soil fertility replenishment mechanisms are essential for enhancing the sustainability and productivity of lowland rice farming systems in inherently unfertile soils in Southeastern Nigeria.

5 ACKNOWLEDGEMENT

We thank the Japan Society for the Promotion of Science (JSPS) and the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of the Government of Japan, for their support to some of the authors in this study.

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