WATER MANAGEMENT PRACTICES FOR SUSTAINABLE RICE PRODUCTION IN NIGERIA.

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ABSTRACT

The lowland elite rice varieties with good management could yield up to 6 tons per ha. These potentials are never achieved on farmers' field because of poor water control system and bad soil management. This is why a renewed call for a concerted effort needs to be made for better water and soil management practices referred to in this paper as Sawah System. Using the Sawah package* we have increased farmers grain yield of rice to between 3 to 5 t/ha consistently in the last 5 years, while the traditional system still average only 1.5 t/ha.

Keywords: Rice production, Sawah system, Water management,

INTRODUCTION

The importance of rice in Nigeria is no longer the question but rather how can we meet the growing demand, reduce import and be self-sufficient.

The green revolution in the 1960s laid the foundation for the rapidly growing economies of Asia today (Hirose and Wakatsuki 2002). Unfortunately, Africa is yet to attain its green revolution. Many theories and hypotheses were tried for our rice production systems yet we haven't gotten to that self sufficiency level. It is now believed that the main cause of the present agricultural and environmental crises in Nigeria and in West Africa is the general under development of lowland agriculture as compared to the Asian countries. This leads to our poor water control abilities for lowland agriculture specifically for rice and subsequently low yields and unsustainable production. This is understandable because we are traditionally upland farmers mostly. Therefore more effort has to be put in place for water management practises especially for our rice cultivation. This is the reason for the sawah system. Hirose and Wakatsuki (2002) defined the term *Sawah* system to mean puddled and levelled rice field surrounded by bund with inlet and outlet connecting irrigation and drainage canals. (The term originates from Malayo-Indonesia. The English term, Paddy or Paddi, also originates from the Malayo-Indonesian term Padi, which means rice plant. The term Paddy, refers to rice grain with husk in Nigeria and West Africa as a whole. Most of the paddy fields in the Asian countries correspond to the definition of the term *sawah*. Paddy field is almost equivalent to *sawah* for Asian scientists. However, the term paddy fields refers to just a rice field including upland rice field in West Africa. Therefore in order to avoid confusion between the terms rice plant, paddy, and the improved man-made rice-growing environment through ecological engineering, the authors propose to use the term *sawah*).

** Sawah package consist of the Sawah system which is leveled field surrounded by bund with inlet and outlet connecting irrigation and drainage canals, row transplanting of improved variety and the application of fertilizer.*

Sawah is a multi-functional constructed wetland, which is the prerequisite for realizing the green revolution as well as for preserving and even restoring ecological environments (Wakatsuki *et al.,*2004). In the absence of good water control system, fertilizers cannot be used efficiently. Consequently, the high yielding varieties perform poorly and soil fertility cannot be sustained, actually erosion is accelerated. Hence, the green revolution cannot take place.

As shown in Fig. 1, the soils formed in uplands and the nutrients released during weathering and soil forming processes in uplands are eroded to the lowlands. If *sawah* system exists in the lowlands, it can store and effectively use these nutrient rich water and fertile top-soils. This is an eco-environmental basis for long-term sustainability of high productivity of *Sawah* based rice farming in Asia.

Suppose the soil formation rate in uplands, which make up 95% of the total area in the example of a watershed as shown in Fig. 1, is 1 ton/ha/yr. In a stable ecosystem in a watershed, the rate of soil formation and erosion should be well balanced; therefore, the top-soils formed in uplands - which account for 95% - and the nutrients produced in the process will be concentrated in the lowlands, which make up 5% of the area. Thus the soil formation rate in the lowlands equals 20 t/ha/yr. Though it will be impossible to use all of the rich soils and nutrient rich water from the uplands effectively, *Sawah* will be the best system for making an effective use of them(Hirose and Wakatsuki 2002 and Wakatsuki *et al* 2004).

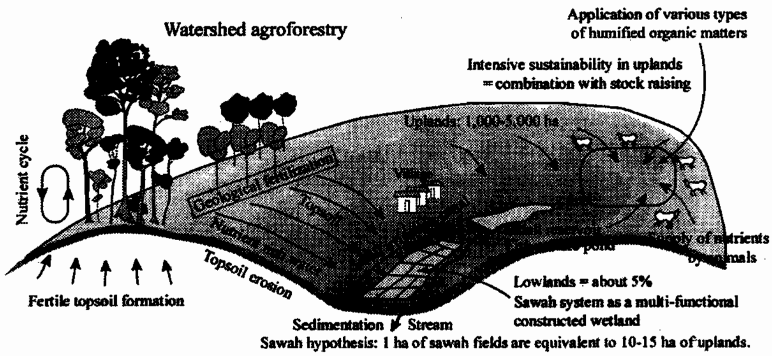

Fig 1: Watershed Agroforestry by the integration of forestry and sawah in a unit Watershed

A *sawah* system in lowlands is, as it were, the one for effectively using the interest accrued from the huge stocks named "uplands." This farming system could artificially reinforce the geological fertilization processes, which are lowland soil formation and regeneration of the soils (Hirose and Wakatsuki, 2002). Fertile topsoil formed in forest ecosystem and sedimentation of the eroded topsoil in lowland sawah is the geological fertilization process (Wakatsuki, *et al* 2003 and 2004). The quantitative scientific evaluation of the geological fertilization process in a watershed will be an important future research subject.

When the unit yields of upland slash and burn rice cultivation is compared to that of lowland *sawah* rice cultivation, the latter (2.5 t/ha) is approximately 2.5 times higher than the former (1 t/ha) under the condition of no fertilizer application (Hirose and Wakatsuki 2002). With standard fertilizer application, the unit yield of *sawah* rice increases to 5 – 6 t/ha (Fashola *et al* 1996 and Wakatsuki *et al* 2004). In contrast, fertilizer application is not a viable option for rainfed upland rice cultivation because of its low efficiency unless infrastructure or land consolidation is provided to a certain degree by means of soil erosion prevention measures. In addition, the planting of rice in rainfed upland areas based on the slash and burn method of farming must be followed by a fallow period of at least 4 – 5 years to allow restoration of the soil fertility, i. e., for the sustainability of 1 ha of upland rice cultivation based on slash and burn, 4 - 5 ha of upland are required. In comparison, continuous cultivation is possible with sawah fields as they have various mechanisms to restore the soil fertility by geological fertilization in the watershed (Fig. 1) and cultivation under submerged water condition (Fig.2). *Sawah* fields can, therefore, contribute to not only increased food production but also conservation of the forest environment as well as soil and water conservation in the catchment area, resulting in the enhanced sustainability of an intensive lowland *sawah* field system (Hirose and Wakatsuki 2002, Fashola *et al* 2004, Wakatsuki *et al* 2004).

Rice Cultivation in Nigeria

Nigeria is the largest producer of rice in West Africa, producing over 46% of the regions total production (Singh *et al* 1997 and FAOSTAT, 2007). In the last 30 years production has increased 6 folds with Nigeria producing 3.3 and 3.6million tons of paddy rice in 2000 and 2005 respectively (FAOSTAT, 2004 and 2007). Nigeria is equally the largest importer of rice and its importation figure stood at 1 million tons costing over $300 million by 1998, which is one third of the sub regions total. It has a land area potential for rice estimated to be 5 million hectares of which 65% are lowlands. In 1999 area harvested from rice was 2.2 million ha. Consumption per capita jumped from 2.9 kg in the period 1970-74 to 24.1 kg between 1995 and 1999 (Hirose and Wakatsuki, 2002). Rice is undoubtedly the most important staple food for the urban dwellers and the fourth largest crop produced after sorghum, millet and maize. But its potential for growth out weighs other cereals.

The fact that rice is the only crop that can be grown in all the agro-ecological zones of Nigeria is an added advantage. Therefore Nigeria has all the growing ecologies for rice viz: 1) rainfed upland, 2) rainfed lowland, 3) irrigated lowland and 4) deep water /floating. According to WARDA, (1999) the percentage of area under rice by ecology is as follows 31% for upland, 47% for lowland, 16% for irrigated and 5% for deep water. There are 57 improved varieties released in Nigeria of which 42 varieties are for lowlands, they had been tested and proven to be responsive to fertilizer and capable of yielding up to 6 tons per ha but the average national yield per ha is still 1.5 t/ha (Singh *et al* 1997). Despite the increased production, the productivity per unit area had only experienced a marginal increase. In order to put this in perspective for better understanding, yield (per square meter) in the last 30 years increased from 1.3 t/ha to 1.8 t/ha whereas in tropical Asia during the same period (1970-2000) yield increase doubled from 1.8 t/ha to 3.6 t/ha (Wakatsuki *et al.*, 2003).

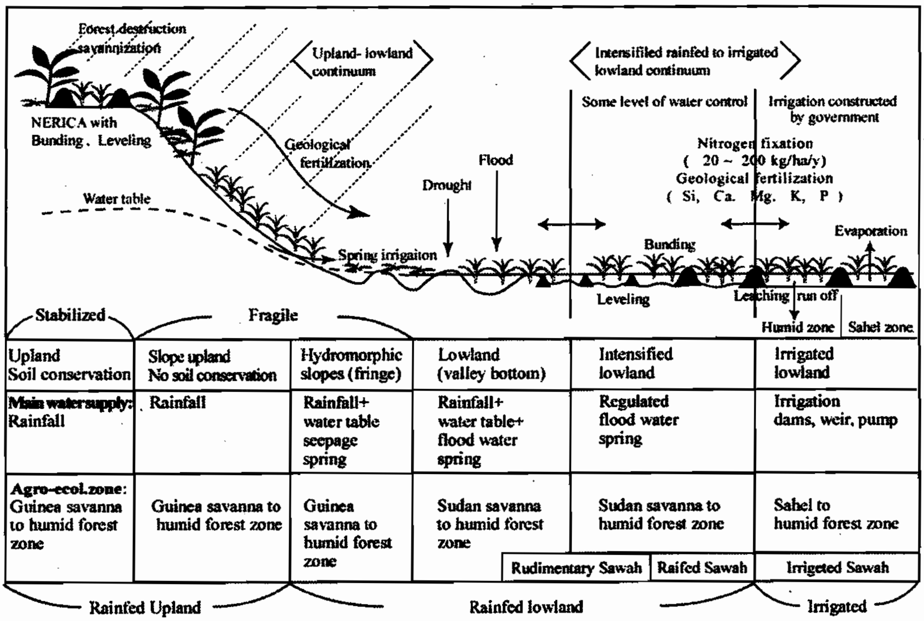

Fig 2: Rice ecologies along a continuum of inland valley watershed and floodplains

Rainfed Lowland

In Nigeria rainfed lowland currently accounts for 47 per cent of the area cultivated to rice although its potential could be 65 per cent. Rice cultivation here takes place at sites where the amount of available water exceeds the annual rainfall level due to the topographical condition of lowland. Rice is cultivated on such land with different levels of water management depending on the experience and skill of the rice farmers. Rainfed lowland can be classified into the following two categories based on the topography and type of development even though it is difficult to draw clear boundary lines between them (Wakatsuki *et al.* 2003) (Fig 2).

(a) Hydromorphic slope (Fringe)

In the case of hydromorphic slopes in a groundwater fluctuation area, it is possible to gain access to seepage and spring water in addition to rainwater and groundwater. In such a case, multiple block irrigation is possible. Such multiple block irrigation in the form of small compartment quasi-*sawah* fields (Rudimentary *sawah*) is widely observed in inland small lowland areas near Bida in Nigeria using spring water (Ishida *et al* 2001; Hirose and Wakatsuki 2002).

(b) Inland Valley Bottom

The size, micro-topography and river flow rate of an inland valley (IV) bottom plains vary depending on the annual rainfall, size of the catchment area and geological as well as topographical conditions. When the catchment area is small (approximately less than 500 ha for a tropical forest belt, less than 2,000 ha for a transitional forest zone, less than 3,000 ha for savannah in Guinea or less than 5,000 ha for savannah in Sudan), it is rare for the water flow of a river to continue for more than half of the year with flooding of inland valley bottom lowland seldom being observed. Normally, the width of an inland valley bottom plain does not exceed several hundred meters and the flood discharge does not exceed several tons per second. When a catchment area is larger than the above case, the flow of river water continues for 6 – 10 months with flooding to a certain extent (Windmeijer and Andriesse, 1993)

In the case of small lowland areas situated in a catchment area of up to the above-mentioned size, the development of infrastructure for water control is possible based on joint work by a village-farmers' group with some assistance provided by an engineer of a public organization. In the history of *sawah* field development in Japan, primary development in the Yayoi Period, *sawah* based rice cultivation which started in Japan about 3000 years ago, was made possible by weirs constructed across small rivers (Honma, 1998). This is the simplest way of creating a *sawah* field system in Nigeria, which has no previous experience of *sawah* rice cultivation.

There has been little effort so far to localise *sawah* system development technologies to support the self-help efforts of local engineers, extension workers and farmers' groups in West African.

The objective of this study is to develop suitable ecological engineering technologies (Eco-Technologies) for integrated watershed/rural development through increasing sustainable productivity and at the same time through improving the total water cycling in a given watershed. Eco-technologies should be adaptive to indigenous farming systems and rural village society. The study therefore compared the *sawah* system method of water management with the traditional system in selected villages around Bida, Niger state, Nigeria.

Materials and Methods:

In 2001 when this study began various areas of benchmark watersheds, which are located 10-30 km southwest from Bida, have been selected for basic agroecological survey. Soil samples were taken from selected villages (sampling depth 0-15cm) using the soil augur. The samples were taken from both upland and lowland ecologies, to compare the chemical properties. These were analysed at IITA analytical laboratory using standard procedures reference IITA Manual series No 7(1982).

Farmers volunteers were used for the study in each village and each farmer gave a minimum of 0.2ha plot from their rice field at the initial stage. However, by 2006 some farmer had given up to 1ha plot for the *sawah* package (Fashola *et al.*, 2007).

Since 2001/2002, when the *sawah* systems as a technology was introduced to the Bida rice farmers of Niger State, the farmers were left to solely manage their fields; the only input supplied was the power tiller used for their land preparation. However, a monitoring of the various activities by the farmers were done and the farmers was grouped into two categories namely:1) farmers with puddled and bunded fields (sawah plot) and 2) farmers with traditional tillage system (non-sawah plots). Sawah plots used the power tiller to puddle the land. After bunding, each plot was between $400m^2 - 600m^2$ which was the major water control measure whereas the non-*sawah* plots were not bunded and not puddled. All farmers used about 30 kg N/ha of fertilizer and transplanted improved variety – WITA 4 (FARO 52).

Grain yield samples were taken from the same individual farmers with both the sawah package and their non-sawah system for comparison for four years (2002-2005) in six villages namely Ejeti – E, Emistundanda – Em, Kpatagi – Kp, Nasarrafu – N, Manbuhari – Mb, and Doko - D.

RESULTS AND DISCUSSION:

Rice Soil Conditions

Lowland soils are generally more fertile than the upland soils as shown in Table 1. It is also known that all lowlands have better texture especially more clay percentages than the uplands data not shown. As explained earlier, they equally possess through proper management the geological fertilization ability for sustainable long-term usage. Available phosphorus is seen as low but with *sawah* system available phosphorus levels is released especially in the 0-5cm level of the soil. Iron deficiencies, that are fast becoming a problem in upland soils due to continuous use, are not a problem with the lowland soils. Balance nutrient level coupled with good cultural practices make the iron toxicity observed in some fields manageable. Farmers are known to plant on ridges in combination with tolerant modern varieties to escape the effect of iron toxicity.

An observable feature of the rainfed lowlands is the wide variability of the soil chemical properties, which are due to their relative position on the toposequence, water control system in place and the farming practices. The development of the *sawah* system will over time homogenise the soil nutrient, increase and build up the clay through the sedimentation of the erosion water coming from the upland.

Table 1: Selected lowland and upland soil chemical properties from fields around Bida

	LOCATIONS						
Parameters measured	Ejite lowland	Emitsun lowland	Emitsun lowland	Emitsun upland	Emitsun upland	ManBuh upland	ManBuh upland
pH	4.4	5.3	5.0	5.5	6.0	5.1	4.9
Total N (g/kg)	**0.69**	**0.64**	**0.97**	**0.30**	**0.26**	**0.20**	**0.20**
Organic C (%)	0.66	0.60	1.20	1.50	0.63	0.26	0.21
Available P (ppm)	2.70	0.66	0.93	0.76	0.70	1.60	1.70
K (cmol/kg)	0.06	0.16	0.21	0.31	0.20	0.04	0.04
Ca (cmol/kg)	1.40	1.23	1.58	1.47	1.37	0.50	0.40
Mg (cmol/kg)	0.2	0.56	0.55	0.45	0.50	0.1	0.1
Fe (ppm)	386.8	151.9	167.6	18.1	8.9	205.3	159.2
Zn (ppm)	0.9	0.2	0.04	0.4	0.6	0.6	0.6
Mn (ppm)	33.8	20.2	8.1	25.9	23.8	1.9	2.9

Grain yield under different water management systems.

All farmers' fields with *sawah* technology out yielded the non-*sawah* plots (Fig 3). The yield range for the *sawah* plots was from 3.5 to 5.5 t/ha whereas the non-*sawah* plot had a range of between 1.2 and 1.9 t/ha. These high yields of *sawah* plots agreed with what IITA scientists observed in their trials conducted between 1986-1992 with various on-farm trials on farmer's fields either as farmer-managed or researcher-managed trials (Fashola *et al.*, 1996). On the *sawah* plots, higher yields were equally observed with plots that had Azolla on their field. In Fig. 3; the E-2 and E-3 were plots with Azolla. The *sawah* system i.e. the puddled, levelled and bunded, enhanced the nitrogen fixation ability of Azolla.

From our diagnostic survey the farmers had mentioned labour as a major constraint in lowland rice cultivation especially in the inland valley swamps. It is observed that if the power tiller (a hand driven two-stroke engine machine) (Fig 4) is introduced and adopted by rice farmers, labour constraints would be overcome. The added benefit is that the water management would be enhanced, and adoption of *sawah* technology could be possible and made easy.

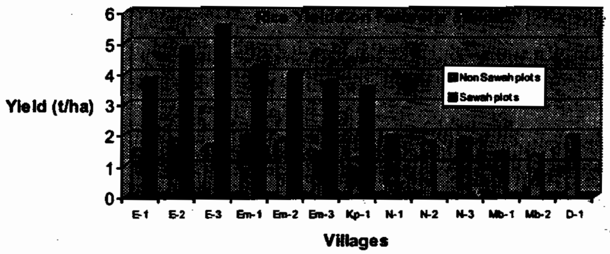

Fig 3: Yield Comparison between Sawah and non-Sawah plots on Farmers' Field

Fig 4: Leveling and puddling (Sawah) on farmer's field at Bida, Niger State

Figure 4 is a demonstration of the use of the power tiller on a farmer's field. The power tiller is a simple two-stroke 13-horse power engine and is a hand driven machine. It is an appropriate technology for the inland valleys (lowland cultivation). It is equally a multi functional and multi-purpose machine and it is affordable. Having bunded the field into manageable plots, the soil can be leveled, puddled and water management is better enhanced. This will enhance the build up of the silt and clay in the water on the plots. The weeds are suppressed given that the rice has a better head-start and reduced weeding frequency had been documented in the literature (Fashola *et al* 2002 and 2004 Hirose and Wakatsuki, 2002). Also fertilizer use efficiency is greatly improved and the high yielding varieties would be able to demonstrate their inherent potential of high yields of between 4 to 6 tons/ha.

CONCLUSION

We can comfortably infer that after four years of comparing the *sawah* system method of water management to the traditional system both managed by the farmers, rice grain yield was consistently higher with the *sawah* system. The use of the power tiller for land preparation equally enhances the *sawah* system productivity. From the selected soil samples taken. Iron and Manganese levels in the lowland soil were generally higher than those from the upland soil.

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