

Exploiting the Potentials of Inland Valleys of Nigeria for Poverty Alleviation

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Abstract

Poverty is steering at the face of most developing countries particularly the Sub-Sahara Africa in spite of the abundance inland valleys which have the potential of growing three crops in sequence within a year without irrigation. 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. The paper highlighted the abundance of this high potential natural resource, existing cropping systems in the inland valleys of Nigeria. It further elucidated (1) the potential of inland valley as a highly productive agricultural land source for resource poor farmer (2) the research interventions to increase productivity, and 3) other relevant issues pertaining to resilience of the systems, were reported. The yields of crops in inland valleys are generally much higher than on the uplands. The naturally abound inland valley in Nigeria is a high resource potential for food crop production. It is robust and resilient resource that could support triple cropping systems on sustainable basis without the fear of deterioration. Each component of the triple crops in the inland valley out yielded the single crop in the upland counterpart. Thus, for Nigeria and indeed Africa to be food sufficient, judicious management of wetlands may likely be the pathway to satisfactorily meeting the food supply of teaming population of a continent plagued by poor soils, drought and environmental destruction.

Key words: Inland valley, triple cropping systems

Introduction

Inland valleys which could also called 'bas-fonds', 'marigots', 'dambo', 'dwala', 'fadama', 'akuro' or 'vlei', are one of the various categories of wetlands, and are, perhaps, best defined in relation to the entire West African landscape. Tarnocai (1979) defined wetland as land 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, hydrophytic vegetation, and various kinds of biological activities 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 (grazing and crop production) and are important to international biodiversity as breeding grounds for migratory birds (World Bank, 2006). Inland valley is known to have considerable potential for intensification and sustainable land use (Izac *et al.*, 1991; Windmeijer and Andriessse, 1993).

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 points to 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 Andriessse, 1993). In rural West Africa, less than 10% of an estimated 55 million ha of wetlands are currently being used for agriculture (Thenkabail *et al.*, 1995) suggesting that wetlands are grossly underutilized for food crop production in comparison to the Asia continent.

Nigeria has eight fadama areas (inland valley or flood plain). These include the Sokoto Basin, Chad Basin, Middle Niger Basin, Benue Basin, Southwestern Zone, South-Central, Southeastern and Basement Complex (World Bank 2006). 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 success recorded in the First National Fadama Project stimulated the interest of World Bank in partnership with Global Environment Facility (GEF) to commit US\$10 million grant to Second National Fadama Project to sustain it in 2006 (World Bank, 2006). The involvement World Bank in the Second and Third National Fadama Projects has popularized the use of fadama among farmers in Nigeria as a high potential resource for the production of fish, lowland rice, vegetables and other arable crops. It is pertinent to note that since inception, the First National Fadama Project in 1999 and the intervention of World Bank in second and Third Fadama Projects have not brought remarkable increase in rice production in Nigeria because rice was not a component of fadama project. For example, between 2001 and 2003, rice production in Nigeria was estimated at 2.03 million tonnes while consumption was 3.96 million Mg. The balance of 1.90 million Mg was obtained by importation (FAO, 2004). Whereas 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 (FAOSTAT, 2008), ironically, Nigeria is the second largest importer of rice in the World after Philippine (Africa Rice Center, 2008a). In West Africa, Nigeria is the leading producer of rice in the West Africa sub-region [Africa Rice Center (WARDA), 2008b] but the quantity produced is far below consumption. Therefore, effective use of inland valleys to increase the crop production appeared to offer the greatest potential for closing the gap between production and consumption. Consequently, employment generation and poverty alleviation in the country will be enhanced. The

objectives of this paper are to highlight the abundance of this high potential natural resource and the existing cropping systems in the inland valleys of Nigeria. It further elucidates (1) the potential of inland valley as a highly productive agricultural land source for resource poor farmer (2) the research interventions to increase productivity, (3) technologies that have enhanced the environment of inland valley for crop productivity to alleviate poverty and (4) other relevant issues pertaining to resilience of the systems.

Soil Biochemical Transformation of Nutrients under Waterlogged Conditions

The most characteristic management practice in paddy rice cultivation is water logging, or submergence of the land surface. This brings about anaerobic conditions in the soil, due to the very slow diffusion rate of oxygen through water. Biologically, after the oxygen reserve in the soil is exhausted and aerobic microorganisms have all died, facultative anaerobes dominate for some time. As the anaerobic conditions continue, these microorganisms are gradually replaced by obligate or strict anaerobes (FFTC, 2007). The biological changes are accompanied by a very characteristic succession of chemical transformations of materials. Following the disappearance of molecular oxygen, nitrate is used as a substrate for denitrifiers. Many fermentation reactions based on various organic substrates proceed along with these mineral transformations, producing carbon dioxide, ammoniacal nitrogen, low molecular weight organic acids, and so forth. As the soil becomes even more reductive, sulphate reducers, which are strict anaerobes, produce sulphides; and methanobacteria, also strict anaerobes, produce methane (FFTC, 2007).

Besides soil organic matter, there is another important source of N, i.e. biological N fixation. In paddy soils there are many microbes that are capable of fixing atmospheric N, such as blue-green algae, *Clostridia*, photosynthetic bacteria, and many of the heterotrophic bacteria in the rice rhizosphere. Estimates of the amount of biologically fixed N per crop of rice vary quite widely, but 30 to 40 kg/ha would be a reasonable figure. This amount of N is two or three times higher than the amount of N fixed in ordinary upland soils planted in non-leguminous crops. Interestingly enough, this amount of fixed N can explain the average yields of paddy obtained in unfertilized fields in southeast Asia (1.5 to 2 mt/ha) on the basis of 20 kg of N for 1 mt of paddy (FFTC, 2007). Therefore, paddy soils are equipped with an excellent N cycling mechanism, with an input through biological N fixation and an output through denitrification. This appears to set the basis for sustainability of rice cultivation as an efficient food production system (FFTC, 2007).

All these biochemical changes occur vigorously for the first month after submergence, when readily decomposable organic matter, the energy source for microorganisms, is abundantly available. Past this stage, there will be a period when the supply of oxygen by diffusion, though extremely slow, exceeds its consumption at the soil/water interface. As all the oxygen is trapped by such reduced substances as ferrous and manganese ions at the interface, a thin oxidized, orange coloured layer (normally a few millimeters thick) is differentiated from the underlying bulk of the strongly reduced, bluish-gray plow layer. Manganese oxides are solubilized as a result of reduction to manganese ions, likewise orange yellow to reddish colored iron oxides are reduced to soluble ferrous ions, decolorizing the soil. The great environmental difference between the oxidized and

the reduced layers exerts a profound influence on nitrogen transformation in the later stages of paddy soil management.

Chemical Transformation of Nutrients under Waterlogged Conditions

The flooding of wetland soils alters both pH and the redox potential of the soil influences the availability of other nutrients as well. The pH of both acid and alkaline soil tends to converge on a pH of 7 when they are flooded. The redox potential, a measure of the intensity of oxidation or reduction of a chemical or biological system, indicates the state of oxidation (and hence availability) of several nutrients. In acid soils in a humid climate, P is present mainly in the form of iron phosphate (Fe-P) and aluminum phosphate (Al-P). Neither of these is readily soluble (Kyuma, 2003). There are, of course, organic forms of P that may be released during the process of organic matter decomposition. However, in contrast to N, the quantity of such organic P compounds is normally very low, compared to the mineral forms of P (FFTC, 2007).

In the process of anaerobiosis in paddy soils, iron phosphate tends to be reduced, with a release of some of the P in available forms. Moreover, reduction of iron oxides releases some of the occluded P into the soil. The reduction of paddy soils under submerged conditions is accompanied by an elevation in soil pH. This is the result of H^+ consumption as oxidized materials, such as NO_3^- and Fe_2O_3 , are reduced. Usually the pH of acid paddy soils stabilizes at around 6.5. The rise in pH enhances the solubility of iron phosphate and aluminum phosphate, by a factor of 10 times per unit rise in pH. This is another mechanism to raise the availability of P in paddy soils (Redman and Patrick, 1965; FFTC, 2007). The availability of major ions such as potassium, magnesium, sulphur and several trace nutrients such as iron and manganese is also affected by hydrologic conditions in the wetlands (Mohanty and Dash, 1982; FFTC, 2007).

Geological Transportation of Nutrients under Waterlogged Conditions

Nutrients are carried into wetlands by hydrologic inputs of precipitation, rivers flooding, tides and surface and subsurface groundwater influence. Outflow of nutrients is controlled primarily by the outflow of waters. These hydrologic/nutrient flows are also important determinants of wetland productivity and decomposition. Intra-system nutrient cycling is generally, in turn, tied to pathways such as primary productivity and decomposition. When productivity and decomposition rates are high, as in flowing water or pulsing hydroperiod wetlands, nutrient cycling is rapid. When productivity and decomposition processes are slow, as in isolated ombrotropic bogs, nutrient cycling is also slow (Mitsch and Gosselink, 1993).

The hydroperiod of wetland has a significant effect on nutrient transformation and on the availability of nutrients to vegetation. Nitrogen availability is affected in wetland by the reduced conditions that result from waterlogged soil. Typically, a narrow oxidized surface layer develops over the anaerobic zone in wetland soils, causing a combination of reactions in the nitrogen cycle-nitrification and denitrification that may result in substantial losses of N to the atmosphere. Ammonium nitrogen often accumulates in wetland soils since the anaerobic environment favours the reduced ionic form over the nitrate common in agricultural soils.

Yield Potentials of Inland Valley (Rainfed Lowland) Compared to other Ecologies

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 groundwater 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 for irrigated, rainfed 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, rainfed 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 rainfed 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 1,642,000 ha devoted rice cultivation in Nigeria, 1, 5, 16, 30 and 48% is grown to mangrove swamp, deep water rice, irrigated lowland, rainfed upland and rainfed lowland respectively. In West Africa, however, of the total land area of 4,011,000 ha devoted to cultivation of rice, 4, 9, 12, 44 and 31% is planted to mangrove swamp, deep water, irrigated lowland, rainfed upland and rainfed lowland respectively (Lançon and Erenstein, 2002). Therefore, to increase the production of rice, vegetable and other upland crops, intensified use of the inland valleys is inevitable.

Comparison of Paddy Soils and Upland Soils

The tillage is not as important in paddy soils as in upland soils. As long as enough water is available to keep the soils submerged, the balance between water retention and aeration, which is vital for upland soil, can be disregarded. Furthermore, a heavy clay soils with a very hard, dry consistency is difficult to till under upland conditions, but is relatively easy to plow and till in flooded lowlands with two buffalo or oxen.

The high level of resistance of paddy soils to erosive forces is even more important, from the viewpoint of sustainability. Upland soils tend to be eroded away unless they are properly protected. This is particularly true in the tropics, where the erosivity of rainfall is very high, and where upland soils usually have poor resistance to erosion. Paddy soils are most resistant to erosion when they are terraced and there are ridges around the field, as measures to retain surface water. In addition, paddy fields in the lowlands receive new sediments deposited from run-off that carries eroded topsoil down from the uplands, thus perpetuating soil fertility and productivity.

In upland farming, crop rotation is a necessity to avoid a decline in yield due to diseases and pests that arise from a monoculture situation (soil sickness). In paddy fields, on the other hand, rice can be grown year after year without any clear sign of yield decline, over a considerable length of time. The alternation from aerobic to anaerobic conditions in a yearly cycle of rice farming is the best measure to remove the causes of soil sickness. No pathogens or soil-borne animals can survive such a drastic change in the redox environment.

Cropping Systems in the Inland Valley

During the rainy season, inland valley soils are usually saturated and anaerobic, but they dry up and soon become aerobic in the dry season. Under aerobic conditions the ammonium (NH_4) form of soil mineral N is oxidized to nitrate (NO_3) which may accumulate in the soil or be utilized by the crop grown there (George *et al.*, 1992). Most of the NO_3 that is not utilized by the plant may be lost through leaching and denitrification when the soils are subsequently flooded for rice cultivation

Under traditional farming in Nigeria, one crop of rice is grown per year because swamps are not developed and water flow is not controlled (WARDA, 1993). Some farmers grow one single crop of lowland rice (lowland rice–fallow–fallow) in the main season and abandon the inland valleys until the following year. Most farmers practice double cropping in the inland valleys. That is, lowland rice is planted in the main cropping season between April and May when the rains have become steady and is harvested in August and September depending on the length of maturity of the variety. The inland valleys are then allowed to drain until such a time when the land is no longer saturated and will support upland crop, such as vegetables or maize (*Zea mays* L.) during the dry season (lowland rice–fallow–vegetable sequence). Considerable opportunity exists for growing the third crop between the main crop (lowland rice) and the dry season cropping (Adigbo *et al.*, 2007). This is a niche that has not been fully exploited. This niche is too short to accommodate another lowland rice crop. Moreover, the available moisture may not be sufficient to support a lowland rice crop.

The niche in question covers the months of September, October, November and earlier part of December. The soil in the niche is anaerobic-aerobic transition which is associated with the general reduction and oxidation transformations of nutrient elements. The niche has relatively better weather (longer sunshine hours, cloud-free and optimum temperature for rice crop) than the main cropping season (Adigbo *et al.*, 2010).

Research Intervention Enhancing Productivity of Inland Valley in Nigeria

An experiment carried out in the University of Agriculture, Abeokuta, Nigeria has shown that a third crop could be grown in the niche between the main crop (lowland rice) and the dry season cropping (Adigbo *et al.*, 2007). This same study postulated that early maturing upland rice is the only likely crop that could be optimised in the niche without reducing the yields of lowland and vegetable. However, (Adigbo *et al.*, 2007) reported that the following constraints were associated with the upland rice component during the study: 1) Upland rice sown by dry dibble method in saturated soil had poor establishment due to high moisture and this consequently, led to low yield, 2) the upland rice component in the sequence decreased the overall benefit/cost ratio of triple cropping rather than increasing it and 3) for the three-crop sequence to be economically viable, the cost of production of upland rice component should be reduced so as to increase economic return and benefit/cost ratio.

A study was carried to address the constraint (1) mentioned above and the result showed that up to 2.28 t ha^{-1} of grain yield could be obtained when rice seeds were established by

adopting pre-germinated dibble and transplanted methods in saturated soil (Adigbo *et al.*, 2010). The grain yield obtained in the inland valley was substantially higher than the obtainable grain yield of 1.5, 1.19 and 1.38 t ha⁻¹ as reported by IITA (1990), Adigbo *et al.* (2003) and Africa Rice Center 2008a), respectively in the upland ecology. Adigbo (2008) addressed constraints (2) and (3) above by identifying some varieties of lowland New Rice for African (NERICA) whose ratooned crops were capable of producing grain yields of 2.24 to 4.66 t ha⁻¹. Rice ratooning is the practice of harvesting grain from tillers originating from the stubble of previously harvested crop (main crop) and it enhances rice grain yield without increasing land area because it provides higher resources use efficiency per unit land area per unit of time (Jason *et al.*, 2005).

Rice ratooning offers an opportunity to increase cropping intensity per unit of cultivated area because a ratooned crop has shorter growth duration than the main crop. In addition, ratooned may be grown with 50% less labour, since neither land preparation nor planting is needed while the crop uses 60% less water than the main crop. A yield of the ratooned crop of 50% of the main crop may be achieved if crop management practices are used efficiently (Oad *et al.*, 2002).

It is pertinent to note that intensive crop management practices such as triple cropping in the inland valley enhances nutrient uptake while achieving high yields can be a principal way to achieve reduction of Green House Gas (GHG) emissions from crop production (Snyderet *et al.*, 2007). These authors further added that the following crop, soil, and fertilizer management factors help minimize net Global Warming Potential (GWP): (1) choice of the right combination of adapted varieties or hybrids, planting date, and plant population to maximize crop biomass production; (2) use of tactical water and N management, including frequent N applications to achieve high N use efficiency with minimal opportunity for N₂O emissions; and (3) use of crop residue management approaches that favour a build-up of soil organic carbon in the wetlands.

The performance of cowpea in inland valley during the dry season were not only comparable to upland yield but had a better grain quality than the uplands (Adigbo *et al.*, 2007; Adigbo, 2009a). It also shows that cowpea obtained from the inland valley generally had higher monetary value and benefit-cost ratio than that of the upland. This was attributed to the fact that harvesting period of cowpea in the inland valley coincides with the peak of dry season when agricultural produces are not only scarce but more expensive (Adigbo and Adigbo, 2011). Oloyin variety which, command the highest premium in the market and had similar grain yield with the two improved varieties tested in the inland valley.

Study on intercrop of amaranth and cowpea in the inland valley during the dry season showed that the maturity period of amaranth intercropped with cowpea did not coincide with the flowering and pod formation stages of cowpea when the control of insect pests is crucial to sustain production (Adigbo, 2009a). This makes the mixture of cowpea and amaranth to be compatible in terms of insecticidal spray suggesting that cowpea particularly the local variety that taste better and command higher premium price in the market could be intercropped with amaranth during the dry season when all major food stuffs are expensive. The intercropped further showed that land equivalent ratio was 1.33 –1.90 indicating that that intercrop was more efficient than the usual sole cropping of vegetables during the dry season. Thus, amaranth could be intercropped with cowpea

without the fear of chemical contamination (Adigbo, 2009a). Besides, amaranth, being a leafy crop, responded positively to the residual fertilizer carryover from the preceding lowland rice-upland rice sequence suggesting that it is a better utilizer of N fertilizer than either cowpea or okra (Adigbo, 2009b). This confirms the finding of Mohanty *et al.* (1989) who reported that rice, as a succeeding crop appeared to be a better utilizer of residual fertilizer N.

Sawah Rice Production Systems

The concept and term sawah refers to manmade improved rice growing environment with demarcated, banded, puddled and leveled rice field with water inlets and outlets using power tiller for weed and 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 scarce 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. *Three key learnings:* (1) Sawah system enhances soil and water management which is important for sustainable rice production; (2) The Sawah package increases rice yield significantly; (3) 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 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/year in Japan and 20 – 200 kg/ha/year in the tropics depending on the level of soil fertility and water management (Kyuma 2003, Hirose and Wakatsuki 2002). This amount is comparable with the nitrogen fixation amount 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 also important future research topics.

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

Performance of Lowland Rice-Ratooned Rice Sequence in Inland Valley as influenced by Fertilizer Rates in Sawah Rice Production Systems

The study was carried out to investigate the sustainable triple cropping in sawah rice based cropping systems with minimal fertilizer application. The test crops are lowland rice and ratooned

rice were planted in May, late September and December, respectively and harvested in September and December. The treatments for lowland rice are 90:45:45, 60:30:30, 45:22.5:22.5 and 30:15:15 NPK kg ha⁻¹ as the main plot. The fertilizer rates for the ratooned rice are 0, 30, 60, 90 N kg ha⁻¹ as the subplot. The objectives were to 1) determine the minimum fertilizer rate of sawah rice given the beneficial effects of sawah as expressed in literature 2) investigate the residual effect of sawah rice and N-fertilizer rates on the performance of ratooned rice and 3) evaluate the residual effects of sawah rice-ratooned rice sequence on the performance of okra.



Plate 1: Sand filling bags to control water in sawah rice field after transplanting.



Plate 2: Sand filled bags used to divert water into sawah field



Plate 3: The sawah field 2 two weeks after transplanting and water introduction

The results obtained from sawah field trial showed that the fertilizer rates had similar effects on chlorophyll content of the leaves determined at 11, 12 weeks after transplanting as well as the flag leaf at maturity. The application of 30:15:15 kg NPK ha⁻¹ fertilizer would be adequate to produce maximum grain yield for the main lowland rice crop in sawah rice production systems. However, the plant height and chlorophyll content of the second crop of ratooned rice were influenced by N-fertilizer rates but the grain yields were similar. It also shows that ratooned rice crop treated with 30 kg N ha⁻¹ fertilizer could produce maximum grain yield (1.39 -1.62 t ha⁻¹) that is equal to the obtainable yield in the upland ecology (1.38 - 1.50 t ha⁻¹). The overall grain yield ranged between 4.47 and 5.65 t ha⁻¹ year⁻¹. Sawah rice based production system could enhance the productivity of inland valley with minimal resources that is affordable by the resource poor farmers (Adigbo *et al.*, 2011)

Conclusion

It is very glaring that naturally abundant inland valley in Nigeria is a high resource potential for food crop production. It is robust and resilient resource that could support triple cropping systems on sustainable basis without the fear of deterioration. Each component of the triple crop in the inland valley out yielded the single crop in the upland counterpart. Thus, for Nigeria and indeed Africa to be food sufficient, judicious management of wetlands may likely be the pathway to satisfactorily meeting the food supply of teeming population of a continent plagued by poor soils, drought and environmental destruction..

References

- Abergel J. (1993) Mise en valeur agricole des bas-fonds du Sahel: Typologie, fonctionnement hydrologue, potentialités agricoles. Rapport Finale, CORAF-R3S. Ouagadougou, Burkina Faso, CIEH.
- Adigbo. S.O., Okeleye, K.A., O.J. Ariyo and V.I.O. Olowe. Effects of Mucuna (*Mucuna utilis* L.) residue incorporation and nitrogen levels on the performance of upland rice. Nigeria Agricultural Journal. Vol. 34: 49-57

Adigbo, S.O., Okeleye, K.A. and Adigbo, V.B. 2007. Performance of upland rice fitted into lowland rice and vegetable/cowpea sequence in inland valley, *Agron. J.* 99 (2007) 377-383.

Adigbo, S.O. 2008. Evaluation of Lowland Rice 'NERICA Varieties' and their Ratooning Ability in an Inland Valley.
<http://a-c-s.confex.com/crops/208am/webprogram/Sesion4350.html>

Adigbo S.O. 2009a Performance of cowpea intercropped with amaranth in an inland valley of a derived savanna. *Agricultura Tropica et Subtropica* Vol. 42 (2) 59-64

Adigbo S.O. 2009b. Effects of low land rice-upland rice-vegetables/cowpea sequence on vegetable and cowpea rainfed inland valley *Agricultura Tropica et Subtropica* vol. 42 (3) 2009 10 5-109

Adigbo, S. O., Ojerinde, A. O., Ajayi, O. and Nwilene F. E. 2010. Effects of sowing methods on upland rice in lowland Rice-Vegetable Sequence in Inland Valley *Journal of Agricultural Science and Technology*. Volume 4, No.3 (Serial No.28)

Adigbo, S.O. and Adigbo, V.B. 2011. Effects of site and insecticide application on growth and grain yield of local and improved cowpea varieties in south-western Nigeria *Archives of Agronomy and Soil Science* Vol. 57, No. 2, April 2011, 179–191

Adigbo, S.O.; Wakatsuki, T.; Fabusoro, E.; Alarima, C.I.; Olowe, V.I.O.; Adeyemi, O.R. Alao, O.A. and Odedina, J.N. 2011. Performance of lowland rice-ratooned rice-vegetable sequence in inland valley as influenced by fertilizer rates in sawah rice production systems. 1st International Conference on rice for food, market and development held at the Raw Material Research Development Council, Maitama, Abuja, Nigeria. Available online: <http://www.rice-Africa.com/acceptedpapers/index.html>.

Africa Rice Center (WARDA).2008a. Africa Rice Trends 2007. Cotonou, Benin: Africa Rice Center (WARDA). 84 pp.

Africa Rice Center (WARDA)/FAO/SAA. 2008b. NERICA®: the New Rice for Africa – a Compendium. EA Somado, RG Guei and SO Keya (eds.). Cotonou, Benin: Africa Rice Center (WARDA); Rome, Italy: FAO; Tokyo, Japan: Sasakawa Africa Association. 210 pp

Anon 1993. Rice Almanac. International Rice Research Institute, Los Banos. Laguna. Philippines; 142pp.

Balek, J. 1983. Hydrology and water resource in tropical regions Elsevier publ., Amsterdam, pp 123-134

Bergkamp G., Pirot, J.Y. and Hostettler, S. 2000. Integrated Wetlands and Water Resources Management, IUCN, Gland, Switzerland, 2000.

Becker, L. and Diallo, R. (1992) Characterization and classification of rice agro-ecosystems in Côte d'Ivoire. West Africa Rice Development Association, Bouaké, Côte d'Ivoire. 135 pp.

Becker, M. and Johnson, D.E. (2001) Improved water control and crop management effects on lowland rice productivity in West Africa. *Nutrient Cycling in Agroecosystems* 59, 119-127.

Buri, M.M.; Issaka, R.N. and Wakatsuki, T. (2007): The sawah technology of rice production for lowlands: An effective tool for poverty alleviation in Southern Ghana. Paper presented at the 4th international conference of the Africa soil science society organized at the Ghana Institute of Management and Public Administration (GIMPA), Accra, Ghana from 7th-13th January, 2007.

Dixon, A.B. (2002) The hydrological impacts and sustainability of wetland drainage cultivation in Illubator, Ethiopia. *Land Degrad. Develop.* 13(1), 17-31.

Dixon, A.B. and Wood, A.P. (2003) Wetland cultivation and hydrological management in eastern Africa: Matching community and hydrological needs through sustainable wetland use. *Natural Resources Forum* 27(2), 117-129.

Food and Agriculture Organization (FAO). 1998. Wetland Characterization and Classification for Sustainable Agricultural Development, FAO Regional Office for Africa, Rome, FAO SAFR, ISBN 0-7974-1928-4, 1998. Available online at: http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/003/X6611E/x6611e03.htm

Food and Agriculture Organization of the United Nations (FAO) (2003) World Soil Resources. <http://www.fao.org/ag/agl/agll/wrb/wrbmaps/htm/soilres.htm>.

FAO (2004) Fact sheet No 5 on International Year of Rice www.rice2004.org

Food & Fertilizer Technology Center (FFTC) 2007. Ecological sustainability of the paddy soil-rice system in Asia, Available online at: <http://www.agnet.org/library>, 2007

Gawler, M. (2002) Strategies for wise use of wetlands. Best practices in participatory management. International IUCN, WWF Publication No. 56, Wageningen, The Netherlands.

George, T.; Ladha, J.K.; Buresh, R.J. and Garrity, D.P. 1992. Managing native and legume -fixed nitrogen in lowland rice-based cropping systems. *Plant Soil* 141: 69-91.

Gopal, B., Junk, W.J. and Davis, J.A. (2000) Biodiversity in wetlands: Assessment function and conservation. Volume 1. Blackhuys Publishers, Leiden, The Netherlands. 353 pp.

International Institute of Tropical Agriculture (IITA). 1980. Consolidated report of

UNDP/FAO/IITA Sierra Leone rice project. International Institute of Tropical Agriculture, Ibadan, Nigeria. pp 18-20

IITA, 1988. International Institute of Tropical Agriculture's strategy plan 1989-2000. IITA, Ibadan, Nigeria. pp 85-86

IITA 1990. IITA Annual Report 1989/1990. Ibadan, Nigeria. pp 82-43

Izac, A-M.; Swift, M.J. and Andriessse, W. 1991. A strategy for inland valley agro ecosystems research in West and Central Africa. RCMP Research Monograph No. 5. Research and Crop Management Program, International Institute of Agriculture, Ibadan, Nigeria. 24pp.

Kyuma K. 2003: Paddy Soil Science, 305 pp., Kyoto University Press

Jason, B., James, P.L., and Ronald, P.R. 2005. Fertilization of ratoon rice in Louisiana State University. Journal of Crop Science 53 (2): 10-15.

Lançon, F and Erenstein, O. 2002. Potential and prospects for rice production in West Africa. Paper presented at the Sub-Regional Workshop on harmonization policies and Co-ordination programmes on rice in ECOWAS Sub-Region Accra, Ghana 25-28 February, 2002

Mitsch, W.G. and Gosselink, J.G. (eds) 1993 Wetlands. Second Edition. Van Nostrand Reinhold. New York. pp 114-175.

Mohanty S.K., Panda M.M., Mosaic A.R., Mahapatra P., Reddy M.D. (1998): 15N balance studies in a rice-green gram-rice cropping system. Journal of Indian Society of Soil Science, 46 (2): 232–238.

Oad, F.C; Ponpe, S.C; Memon, N.; Oad, N.L. and Hazzan. Z. 2002. Rice Rationing management. Pakistan Journal of Applied Sciences 2(1): 20-35.

Raunet, M.1984. Les potentialités agricoles des bas-fonds en région inter tropicales: l'exemple de la culture du ble de contre-saison à Madagascar. Agronomic Tropicale. 39:121-135.

Redman, F.H and Patrick, W.H. Jr. 1965. Effect of submergence on several biological and chemical soil properties. Louisiana Agricultural Experimental Station, Bull. No. 592. Louisiana State University. Baton Rouge. 15pp.

Snyder, C.S., T.W. Bruulsema, and T.L. Jensen. 2007. Greenhouse gas emissions from cropping systems and the influence of fertilizer management—a literature review. International Plant Nutrition Institute, Norcross, Georgia, U.S.A. www.ipni.net

Tarnocai, C. 1979. Canadian Wetland Registry. In: Proceedings of a workshop on

Canadian wetlands environment. C.D.A. Rubec and F.C. Pollett (eds) Canadian Land Directorate, Ecological Classification Series No 12, pp 9-38.

Thenkabail, S. Prasad, S. Nolte, C. 1995. Mapping and characterizing inland valley agroecosystems of West and Central Africa: A methodology integrating remote sensing, global positioning system, and ground truth data in a geographic information systems framework, RCMD Monograph, No. 16, IITA, Ibadan, Nigeria, 1995.

West Africa Rice Development Association (WARDA) 1993. Development of lands, in: Training in Rice Production, Instructor's Manual, West Africa Rice Development Association, Hong Kong, 1993, pp. 29-46.

Wakatsuki, T.; Otoo, E. and Olaniyan O.G. (2002) Restoration of degraded inland watersheds in West Africa: eco-technology approach. In: Proceeding of 17th WCSS, 14–21 August 2002, Thailand, 12021–12028

Wakatsuki, T.; Buri M.M. and Fashola, O.O. 2005 Ecological engineering for sustainable rice production and the restoration of degraded watersheds in West Africa. In: Proceedings of rice research conference, IRRI, pp 336–366

Windmeijer, P.N and Andriessse, W. (eds), 1993. Inland valleys in West Africa. An agro-ecological characterization of rice growing environments. Publication 52. International Institute for land Reclamation and Improvement, Wageningen, The Netherlands, 160 pp.

World Bank, 2001. Second Fadama Development Project (SFDP), Livestock Component, Available online at: <http://www.usaid.gov/ng/downloads/markets/fadamalivestock.doc>.

World Bank, 2006. Press Release, Nigeria Receives Aid to Manage At-Risk Water Ecosystems, Accessed on the 8th December, 2006, Available online at: <http://usinfo.state.gov>.