Journal of Environmental Protection, 2024, 15, 527-536
https://www.scirp.org/journal/jep
ISSN Online: 2152-2219
ISSN Print: 2152-2197

Effect of Tillage Practices on Hydro-Physical Properties of Soils in a Rice-Grown Environment in North Central Nigeria

Ebierni Akpoebidimiyen Otuaro[1], John Jiya Musa[2], Felix Oguche[3], Abayomi Ibrahim Kuti[1], Abubakar Ndaman[1]

[1]Civil Engineering Department, Maritime University, Okerenkoko, Nigeria
[2]Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Nigeria
[3]Institute of Water and Environmental Management, Faculty of Agricultural and Food Sciences and Environmental Management, University of Debrecen, Boszormenyi St, Hungary
Email: *johnmusa@futminna.eu.ng

How to cite this paper: Otuaro, E.A., Musa, J.J., Oguche, F., Kuti, A.I. and Ndaman, A. (2024) Effect of Tillage Practices on Hydro-Physical Properties of Soils in a Rice-Grown Environment in North Central Nigeria. *Journal of Environmental Protection*, **15**, 527-536.
https://doi.org/10.4236/jep.2024.155030

Received: March25, 2024
Accepted: May 24, 2024
Published: May 27, 2024

Abstract

This study details soil's physical and chemical properties in a rice-grown environment in Minna environs Niger State, Nigeria, under different soil and water conservation practices. Soil samples were collected at 0 - 10 cm, 10 - 20 cm and 20 - 30 cm, respectively, using a soil auger to determine their physical and chemical properties such as moisture content, particle size, bulk density, particle density, porosity and organic matter. The textural classification determined the percentage dominance of the soil types in each study site location. The moisture content of site 1 ranged between 14.3% to 13.7%, site 2 ranged between 13.2% to 10.2%, site 3 ranged between 15.4% to 13.2%, site 4 ranged between 15.6% to 13.6% and site 5 ranged between 16.1% to 10.9%. The clay content of sites 3, 4 and 5 is higher than that of sites 1 and 2, while the silt contents of sites 1, 2 and 3 are higher than that of sites 4 and 5. The mean value of soil organic carbon from each study location was 2.37%, 2.03%, 2.43%, 2.07% and 2.17% for sites 1, 2, 3, 4, and 5, respectively. Therefore, site 1 is susceptible to erosion because of poor infiltration rate and well-ploughed or cultivated land by the tractor (harrowed). The particle sizes analysis indicated that the soil type in Site 1 and Site 2 is mainly sandy loam, while Site 3 and Site 5 are mainly loamy and predominantly clay loam in Site 4.

Keywords

Degradation, Erosion, Fertility, Irrigation, Management

1. Introduction

Soil and water are essential inputs to agricultural production [1], and in Nigeria, agricultural practice is crucial to the development and livelihoods of most of the population [2]. However, agricultural land use in Nigeria often results in the degradation of natural soil fertility and reduced productivity. Soil degradation during some farming activities sometimes results in soil erosion, sedimentation, and leaching [3]. Berhe *et al.* [4] stated that with the current rate of soil loss through various agents of erosion, the topsoil resource would be rapidly displaced into the sea, ocean, rivers and stream. In Nigeria, low crop production has been linked partly to the poor soil condition caused by previous severe erosion [5]. Soil erosion occurs when soil particles are carried off by water or wind and deposited elsewhere. Erosion begins when rain or irrigation water detaches soil particles. Too much water on the soil surface fills the surface depression and begins to flow with enough speed; this surface runoff carries away the loosed soil [6]. Soil erosion depends on the rainfall's erosivity and the soil's erodibility [7].

The extent of washing away of the soil particles depends on the soil characteristics and type involved, which leads to the concept of erodibility [5]. Soil erodibility is an estimate of the ability of soil to resist erosion based on the physical and chemical characteristics of each soil [8] [9]. Generally, soils with faster infiltration rates, higher levels of organic matter and improved structure have more excellent resistance to erosion [10]. Water is one of the significant factors in rice production, with the increasing scarcity of water, the costs of its use and resource development [11]. Therefore, farmers and researchers are looking for ways to reduce water use in rice production, increase its use efficiency and increase paddy rice yield. Traditional rice cultivation uses floodwater management, which requires various inputs that are costly and time-consuming [11]. Water management is how water is delivered, when, how often, and how much water is used to obtain the maximum yield [12].

The greatest challenge for agriculture in Nigeria is to produce more Rice with less water if food security is to be maintained. Thus, irrigation water use efficiency should play a more significant role in meeting future rice demands [11]. The only solution to the worldwide water shortage and utilization problem is efficiently using agricultural water to improve crop productivity [13]. The irrigation interval method is the most common practice among rice farmers in rural communities of Nigeria. The determination of suitable irrigation frequency that will improve water use efficiency and save costs is significant. Little information is available on improving Rice's water use efficiency in Nigeria's savanna ecological zone. This study is therefore aimed at evaluating the effect of soil and water conservation practices on the physical and chemical properties of soil in a rice-grown environment in North Central Nigeria.

2. Materials and Methods

2.1. Study Area

The study was conducted on the permanent site farm of the Federal University of Technology, Minna, Gidan Kwanu, which is known to have a total land mass of eighteen thousand nine hundred hectares (18,000 ha.). It is located along kilometre 10 Minna—Bida Road, South—East of Minna in Bosso Local Government Area of Niger State. It has a horseshoe-shaped stretch of land, lying approximately on a longitude of 06^0 28^{ll} E and latitude of 09^0 35^{ll} N. The site is bounded Northwards by the Western rail line from Lagos to the northern part of the country, the eastern side by the Minna—Bida Road, and the northwest by the Dagga hill and river Dagga [14] [15].

2.2. Soil Sample Collection

Soil samples were collected at 0 - 10 cm, 10 - 20 cm and 20 - 30 cm, respectively, using a soil auger from each study area. The distance intervals between the sampling points were 10 m within the study area. This spacing is based on the border basins commonly prepared for rice farming. 450 g of soil sample was collected from each sampling point in the field at depths between 0 and 45 cm to determine their physical properties. These properties were determined according to [14] and [15]. The samples collected were based on the soil's tillage condition in the study area. Site 1 is the tilled area by tractor operations (harrowed), while site 2 is manually tilled using the local hoe with small-sized mounds made. Site 3 is a section where the remains of rice stocks and straws are tilled with a tractor, and site 4 is a wet area with remains of rice stocks and straws, which were manually tilled using the hoe. Site 5 is a Plane land manually tiled using the hoe.

The hydrometer method was used to determine the particle size analysis. 50 g of the soil sample from a 2 mm sieve was poured into a conical flask. Next, 50 ml of sodium hexametaphosphate was added to the soil sample in the flask, after which 100 ml of distilled water was added. The solutions were mechanically shaken and stirred to allow the particles to disperse nicely, but they were not done in such a manner as to reduce the sizes of soil particles, so they were allowed to stand for 24 hours. This is in accordance with [5] and [16]. According to Musa *et al.* [17], a correction factor concerning the temperature is added to the hydrometer readings, giving a new value of H (Hydrometer Correction Factor). Equations 1 to 3 were used to determine the percentage components of the various soil components.

$$\%\ \text{Sand} = \frac{100 - (H \times 100)}{\text{Weight of soil}} \tag{1}$$

$$\%\ \text{Clay} = \frac{H \times 100}{\text{Weight of soil sample}} \tag{2}$$

$$\% \text{ Silt} = \frac{100}{\% \text{ sand} + \% \text{ clay}} \tag{3}$$

2.3. Bulk Density

The mass of each empty crucible was determined as M1, after which soil samples were placed in the various crucible of known weight and re-weighed (M_2). The crucible with the soil samples was kept in the oven for 24 hours at 105˚C. After oven-drying, the crucible with the dried soil samples was re-weighed as M_3. The bulk density was calculated as the mass of oven-dried soil per volume of core (g/cm^3), and gravimetric moisture content as the mass of water in the soil sample per mass of the oven-dried soil. Equation 5 below was used to determine the bulk density of the various soil samples.

$$\text{Bulk Density}(BD) = \frac{\text{Mass of Oven Dry Soil}}{\text{Volume of core sampler}} \tag{5}$$

Total soil porosity was determined by the relationship between bulk and particle density.

3. Results and Discussion

Results of the various laboratory analyses for the soil samples collected from each study location are presented in **Table 1**, **Table 2**, **Table 3** and **Table 4**, respectively. The soil textural classification (**Table 1**) for the various soil samples based on the various cultivation practices was conducted using a soil textural triangle. The percentage of sand content recorded generally was observed to be relatively high for all the study locations, which ranged between 43% and 53% when compared with the other components of soil, such as silt content ranging between 11% and 24%, while clay content ranged between 32% and 38%. The results obtained from the Bougocous hydrometer method showed that sites 1 and 2 have higher percentages of sand than sites 3, 4 and 5. Similarly, the clay content of sites 3, 4 and 5 is higher than that of sites 1 and 2, while the silt contents of sites 1, 2 and 3 are higher than that of sites 4 and 5. This result shows that sites 1, 2, 3 and 5 are more suitable for rice production than site 4. This is in accordance with the work of [5], who stated that soil aggregation is essential for the resistance of the land surface to erodibility, and it influences soils' capacity to remain productive. However, water erosion from detachment, rainfall, transport, and runoff are also agents that contribute to land degradation.

Table 2 presents the results of the moisture content of each of the study locations. The results show that the mean moisture content of sites 1, 2, 3, 4, and 5 was determined to be 14%, 12%, 14.30%, 14.50% and 12.80%, respectively. This was similar to the work carried out at a different location in the same study area by Musa and Egharevba, whose moisture content ranged between 10% and 13%. This shows the dryness of the soil within each of the study locations compared with the result of [18], which [19] confirmed that the infiltration rate would be higher when the soil is dry. Many researchers have established that low moisture reduces the cohesiveness among the particles, thus making them freely dispersible by water and other erosion agents. This is in accordance with the work of [20] [21] and [22].

The lowest bulk density value, as presented in **Table 3**, was found in site 3. It ranges from 1.28 g/cm to 1.39 g/cm. While site 4 has the lowest particle density value, ranging from 1.56 g/cm to 1.76 g/cm. Soil and water conservation practices affected the soil bulk and particle density. The lower mean bulk and particle value under integrated measures might be the subsequent effect of reduced soil loss and crop residue through erosion and adding organic matter from plants.

Similarly, works were reported by [23] and [24], who showed lower mean soil bulk and particle value in conserved plots of rice farms than in non-treated cultivated lands. However, data about particle size distribution revealed dominantly sandy loam and loam textural class, which implies that soil and water conservation practices do not alter the soil texture. The result agrees with the finding of [25], who reported a non-significant difference in texture due to soil and water conservation practices.

Table 1. Soil particle size and textural classification result of the study areas.

		Particles size			
Locations	Samples	% sand	% silt	% clay	Textural classifications
Site 1	1	46	19	34	Sandy Loam Soil
Site 2	2	47	23	30	Sandy Loam Soil
Site 3	3	43	24	33	Loam Soil
Site 4	4	53	15	32	Clay Loam Soil
Site 5	5	51	11	38	Loamy Soil

Table 2. Moisture content of each of the study locations.

Locations	Samples	Horizon Depth (cm)	W_1 (g)	W_2 (g)	W_3 (g)	Mc (%)	AMc (%)
		0 - 10	25.168	104.239	90.148	14.3	
Site 1	1	10 - 20	25.529	104.605	86.162	14.0	14.00
		20 - 30	24.941	102.175	82.452	13.7	
		0 - 10	24.073	101.515	87.143	13.2	
Site 2	2	10 - 20	24.861	103.654	89.132	12.6	12.00
		20 - 30	23.942	100.451	79.142	10.2	
		0 - 10	25.986	103.065	93.168	15.4	
Site 3	3	10 - 20	24.676	102.175	92.196	14.3	14.30
		20 - 30	24.918	101.113	90.184	13.2	
		0 - 10	25.023	102.142	96.168	15.6	
Site 4	4	10 - 20	25.147	105.163	93.145	14.3	14.50
		20 - 30	24.186	103.163	92.131	13.6	
		0 - 10	26.012	105.196	96.333	16.1	
Site 5	5	10 - 20	25.023	103.148	94.145	11.4	12.80
		20 - 30	25.140	102.132	90.132	10.9	

Where W_1 is the weight of the crucible container, W_2 is the weight of the crucible container and fresh soil sample, W_3 is the weight of the crucible container and oven-dried soil samples, *Mc is the moisture content of the soil, and AMc is the average soil moisture content.*

Soil and water conservation practices influenced soil organic carbon (OC) of the farmlands within the study area, as observed in **Table 3**. The mean value of soil organic carbon from each study location was 2.37%, 2.03%, 2.43%, 2.07% and 2.17% for sites 1, 2, 3, 4, and 5, respectively. It was generally observed that the soil and water conservation practices and their integration positively impact the soil organic carbon of cultivated lands. This result, therefore, indicates that soil and water conservation practices have a positive role in improving soil organic carbon. This is in accordance with the works of [26] and [27].

Soil Organic matter (SOM) in each study location was different, as observed in **Table 4**. The soil organic matter for sites 1, 2, 3, 4 and 5 were 3.23%, 4.07%, 3.83%, 4.30% and 3.37%, respectively. These results show that if SOM is increased in the soil, the infiltrability also tends to increase. These results are similar to the work of [28]. Furthermore, the average OM for sites 1, 3 and 5 was lesser than those of sites 2 and 4, significantly implying that soil particles are drier. Thus, the shape, size and stability of soil aggregates may affect the infiltration rate of rainwater. For instance, coarse-grained sandy soils have large spaces between each grain, allowing water to infiltrate quickly. These results are similar to the works reported by Zhang *et al*. [29] on the infiltration rates under different dryland conditions in Indonesia.

Table 3. Soil aggregate results of the study locations.

Locations	Samples	Horizon Depth (cm)	Particle Size			Bd	Pd	P	OC	OM.
			% Sand	% Silt	% Clay	(g/cm³)	(g/cm³)	(%)	(%)	(%)
Site 1	1	0 - 10	48	28	24	1.45	2.94	18.20	2.30	4.00
		10 - 20	47	14	39	1.28	1.58	13.60	2.50	2.60
		20 - 30	43	16	41	1.43	1.62	14.90	2.50	3.10
Site 2	2	0 - 10	59	21	20	1.40	2.94	20.30	1.80	4.80
		10 - 20	41	23	36	1.51	1.99	29.70	2.80	4.00
		20 - 30	42	24	34	1.46	3.10	24.10	1.50	3.40
Site 3	3	0 - 10	42	23	35	1.39	1.99	53.50	2.60	2.60
		10 - 20	43	24	33	1.28	2.80	44.50	2.00	4.60
		20 - 30	45	25	30	1.39	2.94	23.60	2.70	4.30
Site 4	4	0 - 10	51	18	31	1.80	1.56	57.10	1.90	5.10
		10 - 20	56	14	30	1.63	1.63	42.30	2.30	3.60
		20 - 30	52	12	36	1.57	1.76	34.10	2.00	4.20
Site 5	5	0 - 10	48	11	40	1.45	1.82	7.05	1.80	2.90
		10 - 20	55	9	36	1.52	1.86	50.20	1.90	3.20
		20 - 30	49	13	38	1.44	1.91	40.30	2.80	4.00

Where Bd is the bulk density, Pd is the particle density, P is Porosity, OC is the Organic carbon, OM is the Organic matter.

Table 4. Summary of results.

Locations	Samples	AMC	ABD (g/cm³)	A.P.D. (g/cm³)	AP (%)	AOC (%)	AOM (%)	APS			Textural class
								% Sand	% Silt	% Clay	
Site 1	1	14.00	1.39	2.05	15.57	2.37	3.23	46	19	34	Sandy Loam Soil
Site 2	2	12.00	1.46	2.68	24.70	2.03	4.07	47	23	30	Sandy Loam Soil
Site 3	3	14.50	1.35	2.58	40.53	2.43	3.83	43	24	33	Loam Soil
Site 4	4	12.80	1.67	1.65	44.50	2.07	4.30	53	15	32	Clay Loam Soil
Site 5	5	14.30	1.47	1.86	32.52	2.17	3.37	51	11	38	Loam soil

Where ABD is the Average Bulk Density, APD is the Average Particle Density, AP is the Average Porosity, AOC is the Average Organic Carbon, AOM is the Average Organic Matter, and APS is the Average Particle Size

The ability of soil to store water depends on the void spaces within it. Thus, water movement within sandy soils is faster than that of tightly packed clay soils. This is in accordance with the works of Musa *et al.* [5] and Musa and Egharevba. The soil analysis results show that the soil storage capacity depends on the soil porosity. The study locations, sites 1 and 2, are primarily sandy soils and have high porosity, making it difficult to store water. This is in accordance with the work of Akilapa [18], who confirmed that soils run through fingers when fetched and quickly dry up when subjected to high temperatures, mainly containing minerals.

4. Conclusion

The effect of soil and water conservation practices on soil's physical and chemical properties in a rice-grown environment in Minna, north-central Nigeria, was conducted. From the various results obtained, the particle size analysis showed that the soil types in Sites 1 and 2 are sandy loam, Sites 3 and 5 are loam, and Site 4 is clay loam, respectively. Some factors affecting water infiltration rate include texture, management practice and bulk density. Sites 1 and 2, with light textured soils, were observed to have a higher infiltration rate than the heavier textured soils of Sites 3, 4 and 5 due to the large conducting pores in sandy soil. Cultivated tilled lands usually have lower infiltration rates than those fallowed soils. However, soil erosion is a cause of soil fertility loss, reducing crop yield and exacerbating the risk of flooding. The study reveals that indigenous soil and water conservation technologies are considered effective conservation methods. Moreover, the sample with the most negligible moisture content was obtained in Site 2, having an average moisture content of 12%. It is therefore concluded that the soil within Site 2 needs particular management practices to ensure a reasonable infiltration rate of water for soil and water conservation because of its poor infiltration rates, which may lead to the occurrence of surface runoff, during which fine soil particles are carried away as a result of water erosion, poor watershed management, rapid population growth and inappropriate use of farming practices that had contributed for a lion share of the losses caused and pose a severe threat to the production of Rice and other crops.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Teshager, A.D., Gassman, P.W., Secchi, S., Schoof, J.T. and Misgna, G. (2016) Modelling Agricultural Watersheds with the Soil and Water Assessment Tool (SWAT): Calibration and Validation with a Novel Procedure for Spatially Explicit HRUs. *Environmental Management*, **57**, 894-911. https://doi.org/10.1007/s00267-015-0636-4

[2] George, O., Duncan, O.G., David, M. and Johnson, K. (2018) Livelihood Assessment of Avocado Growing in Western Kenya and Its Socioeconomic Implications Using Agricultural Extension Services. *International Journal of Agricultural Extension*, **6**, 71-79. https://doi.org/10.33687/ijae.006.02.2286

[3] Sharma, M.P., Samanta, A. and Sharma, K.R. (2018) Degraded Lands and Their Management for Rehabilitation and Improving Crop Productivity. *Journal of Soil and Water Conservation*, **17**, 25-33. https://doi.org/10.5958/2455-7145.2018.00004.8

[4] Berhe, A.A., Barnes, R.T., Six, J. and Marín-Spiotta, E. (2018) Role of Soil Erosion in Biogeochemical Cycling of Essential Elements: Carbon, Nitrogen, and Phosphorus. *Annual Review of Earth and Planetary Sciences*, **46**, 521-548. https://doi.org/10.1146/annurev-earth-082517-010018

[5] Musa, J.J., Anijofor, S.C., Obasa, P. and Avwevuruvwe, J.J. (2017) Effects of Soil Physical Properties on Erodibility and Infiltration Parameters of Selected Areas in Gidan Kwano. *Nigerian Journal of Technological Research*, **12**, 46-54. https://doi.org/10.4314/njtr.v12i1.8

[6] Okorafor, O.O.A., Adeyemo, A.J. and Egwuonwu, C.C. (2017) Determination of Rainfall Erosivity Index (R) for Imo State, Nigeria. *American Journal of Engineering Research*, **6**, 13-16.

[7] Pham, T.G., Degener, J. and Kappas, M. (2018) Integrated Universal Soil Loss Equation (USLE) and Geographical Information System (GIS) for Soil Erosion Estimation in a Sap Basin: Central Vietnam. *International Soil and Water Conservation Research*, **6**, 99-110. https://doi.org/10.1016/j.iswcr.2018.01.001

[8] Deviren Saygin, S., Huang, C.H., Flanagan, D.C. and Erpul, G. (2018) Process-Based Soil Erodibility Estimation for Empirical Water Erosion Models. *Journal of Hydraulic Research*, **56**, 181-195. https://doi.org/10.1080/00221686.2017.1312577

[9] Dou, Y., Yang, Y., An, S. and Zhu, Z. (2020) Effects of Different Vegetation Restoration Measures on Soil Aggregate Stability and Erodibility on the Loess Plateau, China. *CATENA*, **185**, Article 104294. https://doi.org/10.1016/j.catena.2019.104294

[10] Malvar, M.C., Silva, F.C., Prats, S.A., Vieira, D.C., Coelho, C.O. and Keizer, J.J. (2017) Short-Term Effects of Post-Fire Salvage Logging on Runoff and Soil Erosion. *Forest Ecology and Management*, **400**, 555-567. https://doi.org/10.1016/j.foreco.2017.06.031

[11] Alhassan, I., Saddiq, A.M., Ibrahim, A. and Mustapha, Y. (2017) Effects of Irrigation Frequency and Nitrogen Fertilizer Application on Yield and Water Use Efficiency of Lowland Rice (*Oryza sativa* L.) in Northeastern Nigeria. *MAYFEB Journal of Agricultural Science*, **4**, 20-27.

[12] Vories, E., Rhine, M. and Straatmann, Z. (2017) Investigating Irrigation Scheduling

for Rice Using Variable Rate Irrigation. *Agricultural Water Management*, **179**, 314-323. https://doi.org/10.1016/j.agwat.2016.05.032

[13] Kang, S., Hao, X., Du, T., Tong, L., Su, X., Lu, H., Li, X., Huo, Z., Li, S. and Ding, R. (2017) Improving Agricultural Water Productivity to Ensure Food Security in China under Changing Environment: From Research to Practice. *Agricultural Water Management*, **179**, 5-17. https://doi.org/10.1016/j.agwat.2016.05.007

[14] Musa, J.J., Adewumi, J.K. and Ohu, J. (2013) Comparing Developed Runoff Coefficients for Some Selected Soils of Gidan Kwano with Exiting Values. *International Journal of Basic and Applied Science*, **1**, 473-481.

[15] Musa, J.J., Akpoebidimiyen, O.E., Adewumi, J.K., Eze, P.C., Adesiji, R. and Gupa, Y.U. (2020) Influence of Soil Bulk Density and Porosity on Soil Hydraulic Conductivities for Selected Land Management Practice in North-Central Nigeria. *International Journal of Agricultural and Environmental Sciences*, **5**, 1-7.

[16] Bieganowski, A., Ryżak, M., Sochan, A., Barna, G., Hernádi, H., Beczek, M., Polakowski, C. and Makó, A. (2018) Laser Diffractometry in the Measurements of Soil and Sediment Particle Size Distribution. In: Sparks, D.L., Ed., *Advances in Agronomy*, Vol. 151, Academic Press, Cambridge, MA, 215-279. https://doi.org/10.1016/bs.agron.2018.04.003

[17] Musa, J.J., Adewumi, J.K., Otuaro, E.A. and Musa, M.T. (2019) Effect of Water Stress on the Yield of Selected Vegetable Crops in the Southern Guinea Savannah Ecological Zone of Nigeria. *Open Access Library Journal*, **6**, 1-12.

[18] Akilapa, J. (2010) Soil and Water Management in Rice Growing Location: A Review of the Current State of Knowledge. *Annals of the New York Academy of Science*, **1218**, 136-156.

[19] Balasubramanian, V. and Bell, M.M. (2017) Nitrogen, Rice Knowledge Bank, Fact Sheet. http://www.knowledgebank.irri.org/training/factsheets/nutrient-management/item/nitrogen?tmpl=component&print=1

[20] Popoola, H. (2010) Effects of Soil Properties on Erodibility and Infiltration: A Case Study of UNAAB Hostel. Department of Agriculture Engineering, Abeokuta, 1-60.

[21] Tabbal, D.F., Bouman, B.A.M. and Bhuiyan, S.I. (2010) On-Farm Strategies for Reducing Water Input in Irrigated Rice: Case Studies in the Philippines. *Agricultural Water Management*, **56**, 93-112. https://doi.org/10.1016/S0378-3774(02)00007-0

[22] Ethan, S., Odunze, A.C., Abu, S.T. and Iwuafor, E.N.O. (2012) Field Water Management and N-Rates to Save Water and Control Iron Toxicity in Lowland Rice. *Academic Research International*, **3**, 184-201.

[23] Rakkar, M.K. and Blanco-Canqui, H. (2018) Grazing of Crop Residues: Impacts on Soils and Crop Production. *Agriculture*, *Ecosystems & Environment*, **258**, 71-90. https://doi.org/10.1016/j.agee.2017.11.018

[24] Seitz, S., Goebes, P., Puerta, V.L., Pereira, E.I.P., Wittwer, R., Six, J., Van Der Heijden, M.G. and Scholten, T. (2019) Conservation Tillage and Organic Farming Reduce Soil Erosion. *Agronomy for Sustainable Development*, **39**, Article No. 4. https://doi.org/10.1007/s13593-018-0545-z

[25] Datta, A., Ullah, H. and Ferdous, Z. (2017) Water Management in Rice. In: Chauhan, B.S., Jabran, K. and Mahajan, G., Eds., *Rice Production Worldwide*, Springer International Publishing, New York, 13-25.

[26] Hann, D., Salturan, C. and Yun, Z. (2006) Effects on Rice and Control Iron Toxicity in Lowland. *Australian Journal of Basic and Applied Sciences*, **5**, 1324-1433.

[27] Akintola, D. (2010) Soil Erosion and Environmental Management. *Nigerian Journal*

of Agriculture, *Food and Environment*, **10**, 7-13.

[28] Romkens, F., Nnalee, B. and Hugh, S. (2007) Water Management in Rice Production. *College of Agriculture and Natural Resources*, **3**, 13-26.

[29] Zhang, H., Li, H., Yuan, L., Wang, Z., Hann, T. and Zhang, J. (2012) Post Anthesis Alternate Wetting and Moderate Soil Drying Enhance Activities of Key Enzymes in Sucrose-to-Starch Conversion in Inferior Spikelets of Rice. *Journal of Experimental Botany*, **97**, 645-754.