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Evaluation of Soil Sustainability to Maize Production in Yandev, Gboko, Benue State

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Abstract

Soil melioration capacity of rice husk manure and NPK fertilizer was evaluated on sandy loam soil of Yandev, Gboko, Benue State. Maize was used as a test crop. The experiments were carried out at the Teaching and Research Farm of the Akperan Orshi Polytechnic, Yandev (AOPOLY) during the 2023 cropping season. The experiment was laid out in Randomized Complete Block Design (RCBD) of four (4) treatment replicated three (3) times. Plots measuring 16 m^2 *were treated on flat as follows: maize (control), NPK 15:15:15 (300 kg/ha) + maize, rice husk ash (12.5 t/ha) + maize and decomposed rice husk (12.5 t/ha) + maize. The decomposed rice husk and rice husk ash were manually incorporated into the soil to a depth of 10 cm one week before maize were planted. A total of 4 bulked soil composite auger samples were collected at the depths of 0 – 30 cm for physical and chemical analysis across the four treatments. The data collected on soil properties were analyzed using analysis of variance test based on randomized complete block design (RCBD). The sustainability of the soils was assessed in relation to the cumulative rating index (CRI) of the soil degradation rating (SDR) and soil vulnerability potentials (SVP). Slightly moderate to extreme poor soil quality indicators were observed in different soil amendments. The soils of the study site were considered 'sustainable'. This means that under the present conditions, both soil degradation rate (SDR) and vulnerability potentials (Vp) could be sustained with current level of soil quality indicators.*

Key Words: *Sustainability, soil amendment, maize, degradation, vulnerability*

INTRODUCTION

Improving and sustaining of soil quality reduces fertilizer and pesticide use, improves the air and water quality and helps to prevent the release of greenhouse gases into the atmosphere as well as increased the agricultural productivity of country. Soil organic matters are generally one of the most important criteria of soil quality. Soil organic matter has an influence on the processes occurring in the soil and many soil properties (Gulser and Candemir, 2012; Cercioglu *et al.*, 2014; Demir and Gulser, 2015). However, intensive soil processing and taking product is lead to decrease organic matter in soil. Sustainability and soil quality in agriculture are interrelated. Therefore, functions of soil organic matter are also very important for sustainable agriculture and soil quality (Demir and Gulser, 2015). Addition of fertilizer as a regularly has a great impact on soil organic matter Demir and Gulser, 2015). Especially, adequate levels of organic matter content in the soil surface will improve the physical, chemical and biological properties of soil and also will increase the soil quality (Demir and Gulser, 2015). Paddy husks, that is an important problem in paddy agriculture and is a residual after paddy harvest, is important in terms of recycling to agricultural lands by composting, as well as ensuring sustainability of soil productivity and also contributing to production by improving physical and chemical properties of soils.

The use of rice straw and rice husks in the field has been practiced for some time (Milla *et al*., 2013). Research has shown that incorporation of rice straw and rice husks can significantly improve soil properties by decreasing soil bulk density, enhancing soil pH, adding organic carbon, increasing available nutrients and removing heavy metals from the system, ultimately increasing crop yields. Similar studies on cowpea, soybean, and maize have also supported the application of biochar as a way to increase crop yields (Milla *et al*., 2013). Biochar is commonly defined as charred organic matter, produced with the intent of being deliberately added to soil to improve its agronomic properties. On average, one ton of dry biomass can create 400 kg of biochar containing 80 to 90% pure carbon (Lehmann *et al.*, 2009) at 300 to 700 °C, under low (preferably zero) oxygen concentrations. Rice husk contains a high content of silicon and potassium, nutrients which have great potential for amending soil.
Human activities have either direct or indirect effects on the sustainability of land, thereby threatening its continuous productivity. This consequently, affects agricultural production. Loss of biodiversity, climate change and land degradation due to population pressure in developing countries, poverty and poor performance of extensive agriculture are such factors that make farmers to have problems in sustainable production activities. Soil is therefore managed in order to conserves agricultural land, biodiversity and food security for the country.

The study was carried out to evaluate the sustainability of the soil to maize production in Yandev.

MATERIALS AND METHODS

Study Area

The experiment was conducted at the Teaching and Research Farm of the Akperan Orshi Polytechnic, Yandev during the 2023 cropping season. The area is located at about 4 km north – east from Gboko Town along Gboko – Makurdi road in Gboko Local Government Area of Benue State. The study area is bounded by longitudes $8^0$36’ and $8^0$45’E and latitudes $7^0$45’ and $8^0$00’N.

The climate of the study area is tropical savanna. The minimum temperature is 25^0C and maximum is 33.5^0C. The mean monthly temperature is 27.3^0C. The total annual rainfall varies between about 900 and 1200 mm. The study area has distinct dry and wet seasons. Rainy season starts in March/April and ends in October/November.

The vegetation in the study area is Guinea Savannah type, characterized by grasses with few scattered shrubs and trees. The land in the study area is used for cultivation of crops such as yam, cassava, guinea corn, maize, millet, groundnut, soyabean, benniseed, rice, melon, and other vegetable crops. Trees crops such as mango, palm trees, citrus, cashew and other economic trees are also found in the area.

Field Methods

Application of soil amendments

The experimental plots were laid out on cultivated land area of 20 x 20 m^2. A total of 12 plots were mapped out and each plot measuring 4 m x 4 m (16 m^2) was demarcated by 1m apart as alley ways. The experiment was laid out in Randomized Complete Block Design (RCBD) of four (4) treatment replicated three (3) times. The land was plough manually to a depth of approximately 15cm with big holes before application of treatments. The plots measuring 16 m^2 were treated on flat as follows: Maize (control), (300 kg ha^{-1}) NPK + maize, (12.5 t/ha) rice husk ash + maize and (12.5 t/ha) decomposed rice husk + maize. Decomposed rice husk and rice husk ash were separately applied in the field at one week before maize were planted. The decomposed rice husk and rice husk ash manures were manually incorporated into the soil to a depth of 10 cm at the rate of 12.5 t ha^{-1}. NPK 15: 15: 15 fertilizer was applied at the rate of 300 kg ha^{-1} at one week after planting (1 WAP).

Soil sampling

The physical and chemical compositions of the soil of the study site were determined before application of treatment and after Maize harvest. Three composite soil samples were taken at the depth of 0 – 30 cm in each plot. The 3 samples in each plot were air dried, bulked accordingly and gently crushed. A total of 4 soil samples from the four treatments were sieved using 2.0 mm sieve for physical and chemical analysis.

Laboratory Methods

The relative proportion of the soil separates was determined by hydrometer method of Bouyoucos (1951) (Udo *et al*., 2009). The glass electrode method was used to determine the soil pH (Udo *et al*., 2009). Organic carbon (OC) content of the soil samples were determined by the chromic acid oxidation procedure of Walkley – Black (Udo *et al*., 2009). Extractable bases were determined using the ammonium acetate extract. Sodium and potassium were determined using the flame photometer. Calcium and magnesium were determined using atomic absorption spectrophotometer (AAS) (Udo *et al*., 2009). Total nitrogen was determined using the standard Macro-Kjeldahl method (Udo *et al*., 2009). Bray – I method was used to determine the available phosphorus. Exchangeable acidity (EA) was extracted using the titrimetric method (Udo *et al*., 2009). Cation exchange capacity (CEC) of the soils was determined by Summation (TEB + EA) method (Udo *et al*., 2009). Total exchangeable base (TEB) was obtained by summation of the values of bases [TEB = ∑ (K, Na, Mg, Ca)].

The base saturation (BS) value of the soils was calculated in percentages using the formular; BS = TEB / CEC x 100%

Soil Sustainability to Maize Production

The sustainability of the soils was assessed in relation to the cumulative rating index (CRI) of the soil degradation rating (SDR) and soil vulnerability potentials (SVP) (Table 1). The rating scheme for soil degradation (SDR) (Table 2) and soil vulnerability potential (SVP) (Table 3) suggested by (Lal, 1994) and guidelines for interpretation of soil physical and chemical properties were used in the study.

Weighting sequence for soil degradation rating (SDR) is: 1 = None, 2 = Slight, 3 = Moderate, 4 = Severe and 5 = Extreme.

Weighting order for soil vulnerability potentials (SVP) is: 5 = None, 4 = Low, 3 = Moderate, 2 = High and 1 = Very high.

In this study, eight soil fertility limiting parameters, viz., texture, soil pH, organic matter, total nitrogen, available phosphorus, exchangeable K, Mg and Ca were evaluated and used to assess the rate of soil degradation (SDR) and vulnerability potential (Vp) of the soils of the study area. This is based on the principles and guidelines that “a good soil quality has the least soil degradation rate (SDR) and a poor soil quality has highest SDR and vice versa for vulnerability potentials (Vp)”

Table 1: Sustainability of soils based on cumulative rating index.

		Cumulative rating index	
S/N	Sustainability	SDR	SVP
1.	Highly Sustainable	<20	>40
2.	Sustainable	20-30	35-40
3.	Sustainable with high input	30-35	30-35
4.	Sustainable with another application	35-40	20-30
5.	Unsustainable	>40	<20

Source: (Lal, 1994)

Table 2: Soil Degradation Ratings

		Degradation Rate				
S/N	Soil properties	1	2	3	4	5
1	Texture	Loam	Sil,si,sicl	Cl,cl	Sic,ls	C,s
2	Soil PH	6-7	7-74	7.4-7-8	7.8-8.2	78.2
3	Total Nitrogen(gkg^{-2})	>5.0	3.0-5.0	3.0-2.0	1.5-2.0	<1.5
4	Organic carbon(gkg^{-2})	70-130	45-70	14-45	75-14	<7.5
5	AP(mg kg^{-1})	>20	16-20	8.0-16	2.0-5.0	<2.0
6	Exchangeable ca cmo(+)kg^{-1}	>10.0	8-10	5.0-0.2	2.0-5.0	<2.0
7	Mg	>10.0	5.0-10	3.0-5.0	.05-3.0	<0.5
8	Na					
9	K	>0.16	0.14-0.16	0.12-0.14	0.10-0.12	<0.10
10	Effective CEC	>20	15-20	12-15	10-12	<10
11	Base (%)saturation	<2.5	2.5-4.0	2.4-5.0	5-10	>10
12	Bulk density (mg m^{-3})	<1.3	1.3-14	1.4-1.5	1.5-1.6	>1.6
13	SAR	<3	3-6	6-12	12-20	>20

Source: (Lal, 1994). Foot Note: 1 = Non, 2 = Slight, 3 = Moderate, 4 = Severe, 5 = Extreme

Table 3: Soil Vulnerability

		Vulnerability Rate				
S/N	Soil properties	5	4	3	2	1
1	Texture	Loam	Sil,si,sicl	Cl,cl	Sic,ls	C,s

2	pH	6-7	7-74	7.4-7-8	7.8-8.2	78.2
3	Total N	>5.0	3.0-5.0	3.0-2.0	1.5-2.0	<1.5
4	Organic carbon	70-130	45-70	14-45	75-14	<7.5
5	AP	>20	16-20	8.0-16	2.0-5.0	<2.0
6	Ca	>10.0	8-10	5.0-0.2	2.0-5.0	<2.0
7	Mg	>10.0	5.0-10	3.0-5.0	.05-3.0	<0.5
8	Na					
9	K	>0.16	0.14-0.16	0.12-0.14	0.10-0.12	<0.10
10	Effective CEC	>20	15-20	12-15	10-12	<10
11	Base (%)saturation	<2.5	2.5-4.0	2.4-5.0	5-10	>10
12	Bulk density	<1.3	1.3-14	1.4-1.5	1.5-1.6	>1.6
13	SAR	<3	3-6	6-12	12-20	>20

Source: (Lal, 1994). Foot Note: 1 = Very High, 2 = High, 3 = Moderate, 4 = Low and 5 = None

Statistics Data Analysis

The data collected on soil properties were subjected to analysis of variance (ANOVA) test based on Randomized Complete Block Design (RCBD).

RESULTS AND DISCUSSION

Soil Degradation Rating (SDR) and Vulnerability Potential (Vp) of Soils of the Study Site

Tables 4 – 7 present the rates of soil degradation and vulnerability potential of the soils of the study area. In Table 4 for untreated maize plots, the study revealed that the texture, soil pH and potassium were neither degraded nor being vulnerable to degradation as the SDR/Vp weighting factors showed a ratio of 1/5 which indicated that soils are not degraded and not vulnerable to degradation and therefore better soil quality indicators. On the contrary, the exchangeable Ca status of soils showed a SDR/Vp weighting factor ratio of 3/3 indicating that this parameter is moderately degraded and moderately vulnerable to degradation. Magnesium status of the soil showed a SDR/Vp weighting factor ratio of 4/2 which indicated that the soil is extremely degraded and have high vulnerability potential to degradation. The organic matter, phosphorus and exchangeable K status of the soils seemed to be more alarming with the SDR/Vp weighting factor ratio of 5/1 which showed that the soils have suffered extreme rate of soil degradation and have very high vulnerability potential respectively and therefore, poor soil quality indicators..

Table 5 shows the rate of soil degradation and vulnerability potential of the maize plots treated with 300 kg/ha NPK fertilizer. Soil texture and potassium were neither degraded nor being vulnerable to degradation as the SDR/Vp weighting factor showed a ratio of 1/5 which indicated that soil is not degraded and not vulnerable to degradation and therefore better soil quality indicators. Soil pH showed a SDR/Vp weighting factor ratio of 2/2 indicating that soil is slightly degraded and slightly vulnerable to degradation. Organic matter of soil shows a SDR/Vp weighting factor ratio of 3/3 indicating that these parameters are moderately degraded and moderately vulnerable to degradation. Phosphorus, Mg and Ca of the soil had SDR/Vp weighting factor ratio of 4/2 which showed that the soil has suffered severs rate of soil degradation and have high vulnerability potential. Nitrogen status of the soils has SDR/Vp weighting factor ratio of 5/1 which showed that the soils have suffered extreme rate of soil degradation and have very high vulnerability potential and therefore, poor soil quality indicators.

Tables 6 and 7 presented the rates of soil degradation and vulnerability potential of maize plots respectively treated with 12.5 t/ha rice husk ash manure and 12.5 t/ha of decomposed rice husk manure. Better quality indicators were shown for texture and potassium. These soil properties were not degraded and vulnerable to degradation as the SDR/Vp weighting factors showed a ratio of 1/5 which indicated that soils were not degraded and vulnerable to degradation. Soil pH showed a SDR/Vp weighting factor ratio of 2/2 indicating that soil is slightly degraded and slightly vulnerable to degradation. Organic matter and Ca show a SDR/Vp weighting factor ratio of 3/3 indicating that these parameters are moderately degraded and moderately vulnerable to degradation. Phosphorus and Mg of the soil had SDR/Vp weighting factor ratio of 4/2 which showed that the soil has suffered severs rate of soil degradation and have high vulnerability potential. Nitrogen of the soil had SDR/Vp weighting factor ratio of 5/1 which show that the soil have suffered extreme rate of soil degradation and have very high vulnerability potential and therefore, poor soil quality indicators.

However, though, moderate soil quality indicators at various soil management practices showed moderate rate of degradation and vulnerability to degradation, these soil quality indicators might be good soil quality indicators in the long term if good soil management strategies are adopted as also observed by Amara *et al*. (2014)

Sustainability of the Soil for Maize Production

The sustainability of soils of the study areas has been assessed in relation to the Cumulative Rating Index (CRI) based on the eight soil quality indicators shown in Table 8 for maize plots treated with maize (control), 300 kg/ha NPK, 12.5 t/ha rice husk ash (RHA) and 12.5 t/ha decomposed rice husk (DRH). Maize plots treated with maize (control), 300 kg/ha NPK, 12.5 t/ha rice husk ash (RHA) and 12.5 t/ha decomposed rice husk (DRH) had CRI under SDR of 25, 24, 23 and 23 respectively. Vulnerability potential (VP) values for maize (control), 300 kg/ha NPK, 12.5 t/ha rice husk ash (RHA) and 12.5 t/ha decomposed rice husk (DRH) were 23, 22, 23 and 23 respectively. Based on the cumulative rating index for SDR and Vp of soils and the principle that a sustainable land use has a low cumulative rating index for SDR and Vp, the study reveal that all the soils of the study sites were ‘sustainable’ with the application of organic and inorganic amendments. This means that under the present conditions, both soil degradation rate (SDR) and vulnerability potentials (Vp) could be sustained with current level of soil quality indicators. The results further imply that soils of the study area considered might have been used with maximum management practices for some few years.

Table 4: Soil Degradation Rate (SDR) and Vulnerability Potential (VP) of Soils and Critical Limits (CL) for Interpretation of Soil Fertility for Untreated Maize (Control) Plot

		SDR			VP		
Soil Properties	Values	WF	SDR	CL	WF	VP	CL
Texture	SL	1	None	-	5	None	-
Soil pH (H_2O)	6.8	1	None	High	5	None	High
O.M (%)	0.9	5	Extreme	Low	1	Very High	Low
N (%)	0.05	5	Extreme	Low	1	Very High	Low
P (%)	1.3	5	Extreme	Low	1	Very High	Low
Ca (mg/kg)	2.1	3	Moderate	Low	3	Moderate	Low
Mg (mg/kg)	1.9	4	Severe	low	2	High	Low

K (mg/kg)	0.2	1	None	High	5	None	High
Cumulative Rating Index (CRI)		25			40		

Note: Soil property values were considered between 0 – 30 cm soil depth.
WF: Weighting Factor; SL: Sandy Loam;

Table 5: Soil Degradation Rate (SDR) and Vulnerability Potential (VP) of Soils and Critical Limits (CL) for Interpretation of Soil Fertility for 300 kg/ha NPK + Maize Plot

			SDR			VP	
Soil Properties	Values	WF	SDR	CL	WF	VP	CL
Texture	SL	1	None	-	5	None	-
Soil pH (H_2O)	7.3	2	Slightly	Low	2	High	Low
O.M (%)	1.07	3	Moderate	Low	3	Moderate	Low
N (%)	0.3	5	None	Low	1	Very High	Low
P (%)	2.6	4	Severe	Low	2	High	Low
Ca (mg/kg)	2.6	4	Severe	Low	2	High	Low
Mg (mg/kg)	2.4	4	Severe	low	2	High	Low
K (mg/kg)	0.23	1	None	High	5	None	High
Cumulative Rating Index (CRI)		24			22		

Table 6: Soil Degradation Rate (SDR) and Vulnerability Potential (VP) of Soils and Critical Limits (CL) for Interpretation of Soil Fertility for 12.5 t/ha Rice Husk Ash + Maize Plot

			SDR			VP	
Soil Properties	Values	WF	SDR	CL	WF	VP	CL
Texture	SL	1	None	-	5	None	-
Soil pH (H_2O)	7.3	2	Slightly	Low	2	High	Low
O.M (%)	1.4	3	Moderate	Low	3	Moderate	Low
N (%)	0.3	5	Extreme	Low	1	Very High	Low
P (%)	2.8	4	Severe	Low	2	High	Low
Ca (mg/kg)	3.2	3	Moderate	Low	3	Moderate	Low
Mg (mg/kg)	2.9	4	Severe	low	2	High	Low
K (mg/kg)	0.3	1	None	High	5	None	High
Cumulative Rating Index (CRI)		23			23		

Table 7: Soil Degradation Rate (SDR) and Vulnerability Potential (VP) of Soils and Critical Limits (CL) for Interpretation of Soil Fertility for 12.5 t/ha Decomposed Rice Husk + Maize Plot

			SDR			VP	
Soil Properties	Values	WF	SDR	CL	WF	VP	CL
Texture	SL	1	None	-	5	None	-
Soil pH (H_2O)	7.3	2	Slightly	Low	2	High	Low
O.M (%)	1.4	3	Moderate	Low	3	Moderate	Low
N (%)	0.3	5	Extreme	Low	1	Very High	Low
P (%)	2.8	4	Severe	Low	2	High	Low
Ca (mg/kg)	3.2	3	Moderate	Low	3	Moderate	Low
Mg (mg/kg)	2.9	4	Severe	Low	2	High	Low

K (mg/kg)	0.3	1	None	High	5	None	High
Cumulative Rating Index (CRI)		23			23		

Table 8: Sustainability of Soils in Yandev Based on Cumulative Rating Index

Treatment	SDR	SVP	Sustainability
(T1) Maize (Control)	25	23	Sustainable
(T2) NPK (300 kg/ha) + Maize	24	22	Sustainable
(T3) Rice Husk Ash (12.5 t/ha) + Maize	23	23	Sustainable
(T3) Decomposed Rice Husk (12.5 t/ha) + Maize	23	23	Sustainable

CONCLUSION

In this research, slightly moderate to extreme poor soil quality indicators were observed under different soil management practices. The soils of the study site were considered ‘sustainable’. This means that under the present conditions, both soil degradation rate (SDR) and vulnerability potentials (Vp) could be sustained with current level of soil quality indicators, and is therefore, recommended for maize production.

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