Academic Journal of Current Research
Vol.7, No.4; April- 2020
ISSN (3342 – 543X);
p –ISSN (4519 – 6511)
Impact factor: 8.11

ASSESSMENT OF SOIL MANAGEMENT PRACTICES ON SOIL PRODUCTIVITY USING RIQUIER PRODUCTIVITY INDEX MODEL IN MAKURDI, BENUE STATE, NIGERIA

Kurayemen Chagbe, Philip Ijirbee Agber and Aminu Ali
Department of Soil Science, University of Agriculture, P.M.B 2373, Makurdi, Nigeria

Abstract: Field experiments were carried out at the Teaching and Research Farm of the University of Agriculture, Makurdi, South Core (Latitude 7ºº46'– 7º50'N and Longitude 8º36' – 8º40'E) during the 2018 and 2019 cropping seasons. The experiment was setup to assess the effectiveness of soil management practices on soil productivity using Riquire productivity index (RI) model in Makurdi under rainfed conditions. Physical and chemical properties of the soils of the study site were determined at the beginning and end of the experiment and subjected to productivity index model of Riquier (1970). The experiment was a factorial experiment in randomized complete block design (RCBD), with three tillage methods (zero tillage, ridge tillage and surface hoeing) and four soil amendments (control, 15 t/ha moringa, 10 t/ha poultry dropping and 120 kg/ha SSP) replicated three times. Tillage treatments constituted the main plots with soil amendments in the sub-plots, resulting in total of twelve (12) treatment combinations. Riquier productivity index (RI) model was used in the study to assess soil productivity under various soil management practices. Correlation and regression analyses were performed to test the relationships between grain yields of soyabean and RI at various soil management practices. Riquier productivity index (RI) rating and coefficient of improvement (CI) indicated 'good soil productivity'. The coefficient of improvement indicated 0.64% improvement in soil productivity in 2018 and increased by 1.07% coefficient of soil improvement in 2019. The relationship between grain yield of soyabean and RI showed significant positive correlation (r = 0.569) in the second cropping season.

Keywords: Soil management, soil productivity, model, tillage, yields

INTRODUCTION

The Southern Guinea Savanna Agroecological zone of Nigeria where Benue State is located is characterized by diverse climatic, topographic and soil conditions. This region is one of the areas where various land degradation processes constitute key constraints to soil productivity. Accelerated erosion, drought and soil fertility decline are among the main causes of soil degradation (Lal, 1990, 1994; Piccolo *et al*., 1997; Idoga and Ejembi, 2003). Mismanagement, neglect and exploitation can ruin the fragile soil resource and could become a threat to human survival (Lal and Pierce, 1991). The top soil is generally enriched with organic matter and has granular aggregates that provide larger soil pores, reduce soil density and enhance water infiltration and aeration. When the top-soil is eroded, yield suffers due to nutrient loss and damage to soil physical properties. The loss of top-soil and its impacts on yield reduction have been reported by Mbagwu *et al*. (1984).Sustainable soil management systems must be developed to reduce further degradation and restore the productivity of the eroded land.Soil productivity is the capacity of a soil in its normal environment to produce a particular plant or sequence of plants under a specified management system (Nwite and

Nnoke, 2005). It is also considered as initial soil capacity to produce a certain amount of crop per annum, and is expressed as a percentage of the optimum yield per hectare of the same crop grown on the best soil (Riquier *et al*., 1970). Soil productivity is a function of the intrinsic properties of a soil, first as determined in the process of describing the soil profile and the crops grown on it, and secondly by laboratory analysis. Soil productivity varies with the type of crop grown. Some plants being able to withstand adverse soil conditions which others cannot. A number of soil properties directly affect soil productivity; these include topsoil thickness, texture distribution, rooting depth, soil fertility and slope.

Models are simplifications of realities (Morgan, 1995).The first model of productivity index was used by Chinese (Kiniry *et al*., 1983). Researchers are trying to establish the relationship between soil properties and soil productivity (Follet and Stewart, 1985; ASAE, 1985; Agber, 2011). These, according to Gantzer and McCarthy (1987), Agber (2011), Agber and Ali (2012) have grown out of the need to increase the knowledge of quantitative relationships between plant growth and soil properties which could be affected by soil erosion. Various approaches are being developed, which attempted to numerically relate soil properties to its productivity. It is established that productivity capacities or expected yields are useful in determining the suitability of any soil for agricultural use (De La Rosa *et al*., 1982). Consequently, estimates have been made of the productivity of individual kinds of soil in many places. Attempts have been made to key the yields of crops or pastures to limited number of soil properties (De La Rosa *et al*., 1982; Kiniry *et al*., 1983; Ngwu *et al*., 2005; Williams *et al*., 1983; Agber, 2011) so that the changes in soil productivity are determined in relation to soil erosion. Riquire productivity index (RI) model of Riquire *et al*. (1970) put forward a formula for expressing productivity as a resultant of various factors at play. This productivity index is concerned basically with soil characters that govern its utilization and productive capacity. This considers only intrinsic factors less extrinsic factors such as slope and erosion.Numerous models currently exist ranging from simple to complex, which describe the effect of soil management practices on soil productivity. However, not enough information available in relation to the effects of soil amendments and tillage practices on soil productivity using Riquire productivity index (RI) model in Makurdi area of Benue State, Nigeria.

MATERIALS AND METHODS

Experimental Site

The experimental was carried out at the Teaching and Research Farm of the University of Agriculture, Makurdi, South Core (Latitude 7°46' – 7°50'N and Longitude 8°36' – 8°40'E) during the 2018 and 2019 cropping seasons. The experimental area is characteristic by worm tropical climate with distinct wet and dry season. The wet season starts from April to October with an annual rainfall of about 1137 mm although the amount and duration vary annually.

The soils are underlain with Makurdi sandstone and are moderately deep to deep. The soils are coarse textured; especially in the surface horizons, with variable texture in the surface layers. The soils are well drained to moderately well drained (Agber and Anjembe, 2012).

Experimental Treatments and Design

A total plot size of 17 m x 66 m was mapped and cleared manually with cutlasses and hoes. The experiment was a factorial experiment in randomized complete block design (RCBD), with three tillage methods(zero tillage,ridge tillage and surface hoeing) and four soil amendments (control, 15 t/ha moringa, 10 t/ha poultry dropping and 120 kg/ha SSP) replicated three times. Tillage treatments constituted the main plots with amendments in the sub-plots, resulting in Total of Twelve (12) treatment combinations of experimental plots of 5 m x 5 m (25 m^2) with 0.5m alley between them. The treatment combinations were zero tillage x control, zero tillage x 15 t/ha moringa, zero tillage x 10 t/ha poultry dropping, zero tillage x 120 kg/ha SSP, ridge tillage x control, ridge tillage x 15 t/ha moringa, ridge tillage x 10 t/ha poultry dropping, ridge tillage x 120 kg/ha SSP, surface hoeing x control, surface hoeing x 15 t/ha moringa, surface hoeing x 10 t/ha poultry dropping and surface hoeing x 120 kg/ha SSP.

Treatments Application

Soybeans were drilled on ridges and flats depending on the treatment combination at spacing of 5 cm as recommended by Benue Agricultural and Rural Development Authority (BNARDA). For ridges and surface hoeing, the soil was tilled and inverted to the depth of 30 cm using traditional hoes. Soybeans (TGX 1440 -2E) were used as a test crop. Soybeans were manually planted (two seeds per hole) at 5 cm depth and at 0.5 x 0.75 cm spacing. The seedlings were thinned down to one seed per hole, one week after emergence leaving 53,000 plants per hectare. Lost stands were replaced.

The green manure ie 15 t/ha of moringa (*Moringa oleifera*) and 10 t/ha of poultry droppings were applied one week before planting to allow for decomposition and accompanying heat of decomposition to wear off. Inorganic fertilizer SSP at 120 kg/ha was applied two (2) weeks after planting (WAP), according to the treatment combinations.

Soil Sampling and Analysis

Soil samples of the study site were taken at the beginning and end of the experiment. Random sampling technique was used to collect soil samples from three (3) different points in each plot. Soil auger was used for collection of the soil samples. Composite soil samples were taken at the depth of 0 – 30 cm. Soil samples in each plot were air dried, bulked accordingly and gently crushed. A total of 12 soil samples from the study site were sieved using 2.0 mm sieve for physical and chemical analysis using standard procedures as described by Udo *et al*. (2009).

Application of Riquire Productivity Index (RI) Model

Riquire productivity index (RI) of Riquire (1970) put forward a formula for expressing productivity as a resultant of various factors at play. This productivity index is concerned basically with soil characters that govern its utilization and productive capacity. This considers only intrinsic factors less extrinsic factors such as slope and erosion. Riquire productivity index is given as:

Pa = H x D x P x T x Fa …………………… (1)

Where;

Pa = Soil Productivity

H = Soil moisture based on number of wet/dry months.

D = Drainage

T = Soil texture/structure

Fa = Actual fertility index consisting of several factors such as

(i) = Organic matter

(ii) = pH

(iii) = Base saturation

(iv) = Exchangeable capacity of clay Cmol$^{(+)}$ Kg^{-1}

(v) = Total soluble salts (s)

Actual Fa was calculated separately using equation 2 and the final factor incorporated into equation 1 (Pa).

Fa = O x pH x N x C x S ……………………………. (2)

Where

O = Organic matter

pH = Soil reaction (pH)

N = Base saturation

C = Nature of clay taken as (EC Kg Clay)

S = Soluble Salt content.

Each factor rated on a scale from 0 – 100, the actual percentages being multiplied each other. The resultant index of productivity also lying between 0 and 100 is set against a scale placing the soils in one of the five productivity classes (Table 1). After effecting the possible improvement, the potential productivity rating was worked out and grades were assigned (Riguier *et al*., 1970). Using the same formula (equation 1) as that for

Academic Journal of Current Research
Vol.7, No.4; April- 2020
ISSN (3342 – 543X);
p –ISSN (4519 – 6511)
Impact factor: 8.11

productivity index but assuming the new characteristics, the potentiality index was calculated from the improved characteristics and percentages of increased productivity resulting from management. This was useful in classifying the soils against the potentiality scale. The coefficient of improvement as worked out based on the actual productivity and potential productivity rating as given below: Coefficient of Improvement (CI)

CI = Potential productivity rating
Actual productivity rating…….. (3)

The indices under consideration here were identical with those of productivity scale as presented in Table 1. The values of soil characteristics (soil properties) of the study site were subjected to Riquier productivity index and their ratings for crop growing as described by Riquier *et al*. (1970), Agber (2011), Agber and Ali (2012).

Statistical analysis

Correlation analysis using IBM SPSS version 20 was performed to show the relationships between grain yield of soyabean and Riquier productivity index (RI). A regression equation was developed from the soybean grain yield data and Riquier productivity index (RI) to predict the productivity of the soil.

Table 1: Scale of Productivity (P), Rating, RI – Range and Potentiality (Pi)

P	Rating	RI – Range	Pi
1	Excellent	65 – 100	I
2	Good	35 – 64	Ii
3	Average	20 – 34	Iii
4	Poor	8 – 19	Iv
5	Extremely poor to Nil	0 – 7	V

Source: Riquier *et al*. (1970)

RESULTS AND DISCUSSION

Riquier Productivity Index (RI)

At the startof the experiment (ie before treatment application) in 2018 the results of the investigation show that the ascribed sufficiency values for soil moisture, drainage, soil texture, organic matter, soil pH, base saturation, CEC and soluble salts were 0.9, 0.95, 1.0, 0.9, 0.85, 1.0, 1.0, 0.9 and 1.0 respectively. The calculated Actual Productivity value for Riquier Productivity Index (RI) of the soil was 59. This value (59) falls under productivity class 2 and rated 'good productivity'.

The results of Riquier Productivity Index (RI) after harvest are presented in Tables 2, 3 and 4 for 2018 and 2019 cropping seasons. In 2018, the actual productivity rating was 59 and higher than potential productivity (38) and all the ratings fall under 'good productivity'. The higher actual productivity showed that this land had been left fallow for some few years. Coefficient of improvement indicated 0.64% improvement in soil productivity. This implies that there was little increased in soil productivity after harvest during the first trial. This could be due to plant uptake of nutrients from the soil, leaching of appreciable nutrients and erosion that contributed to the decline in the soil productivity. Delayed in decomposition of soil amendment could also contributed to the low improvement in soil productivity after the first trial. In 2019 cropping season, the actual productivity was 38 and less than potential productivity (40) and all fall under 'good productivity' ratings. Coefficient of improvement shows 1.07% improvement in soil productivity. Coefficient of soil productivity in 2019 was higher than that of 2018. This could be ascribed to increase in soil organic matter, base saturation and CEC of the soil as well as increased in soil moisture content and decomposition of the applied soil amendments.

Application of 10 t/ha poultry manure, 15 t/ha moringa and SSP at 120 kg/ha improved the fertility status of the soil. The higher RI values of the soil properties observed under poultry manure and moringa treatment combinations might be attributed to conservation practices. This reflected the true fertility status of the soils and hence their productivity and therefore, increase the precision of the model. The RI coefficient of improvement values between 0.64 and 1.07 % obtained in 2018 and 2019 indicated improvement or maintenance of soil productivity capacity while using the land, which is the main purpose of soil conservation. This result agree with that of Agber (2011), Agber and Ali (2012) who concluded that soil properties of RI are good indicators for assessing the productivity of the soils within the Makurdi sub humid zone since they influenced soil productivity status.

Table 2: Riquier Productivity Index (RI) and Coefficient of Improvement (CI) for 2018 Cropping Season

Treatment Combinations	Actual Productivity	Potential Productivity	Coefficient of Improvement (%)
1.(TIA1) Zero tillage x control	0.59	0.46	0.78
2.(TIA2) Zero tillage x moringa 15t/ha	0.59	0.39	0.66
3.(TIA3) Zero tillage x Poultry dropping 10 t/ha	0.59	0.35	0.59
4.(TIA4) Zero tillage x SSP 120 kg/ha	0.59	0.41	0.69
5.(T2A1) Ridge tillage x control	0.59	0.47	0.80
6.(T2A2) Ridge tillage x moringa 15 t/ha	0.59	0.35	0.59
7.(T2A3) Ridge tillage x poultry dropping 10t/ha	0.59	0.35	0.59
8.(T2A4) Ridge tillage x SSP 120 kg/ha	0.59	0.33	0.56
9.(T3A1) Surface hoeing x	0.59	0.33	0.56
10.(T3A2) Surface hoeing x moringa 15 t/ha	0.59	0.41	0.69
11.(T3A3) Surface hoeing x poultry dropping 10 t/ha	0.59	0.35	0.59
12.(T3A4) Surface hoeing x SSP 120 kg/ha	0.59	0.33	0.56
Total	7.08	4.53	7.66
Mean	0.59	0.38	0.64

Table 3: Riquier Productivity Index (RI) and Coefficient of Improvement (CI) for 2019 Cropping Season

Treatment Combinations	Actual Productivity	Potential Productivity	Coefficient of Improvement (%)
1.(TIA1) Zero tillage x control	0.46	0.41	0.89
2.(TIA2) Zero tillage x moringa 15 t/ha	0.39	0.44	1.13
3.(TIA3) Zero tillage x Poultry dropping 10 t/ha	0.35	0.35	1.00
4.(TIA4) Zero tillage x SSP 120 kg/ha	0.41	0.44	1.07
5.(T2A1) Ridge tillage x control	0.47	0.35	0.74
6.(T2A2) Ridge tillage x moringa 15 t/ha	0.35	0.44	1.26
7.(T2A3) Ridge tillage x poultry dropping 10 t/ha	0.35	0.44	1.26
8.(T2A4) Ridge tillage x SSP 120 kg/ha	0.33	0.35	1.06

9.(T3A1) Surface hoeing x control	0.33	0.33	1.00
10.(T3A2) Surface hoeing x moringa 15 t/ha	0.41	0.44	1.07
11.(T3A3) Surface hoeing x poultry dropping 10 t/ha	0.35	0.35	1.00
12.(T3A4) Surface hoeing x SSP 120 kg/ha	0.33	0.44	1.33
Total	4.53	4.78	12.81
Mean	0.38	0.40	1.07

Table 4: Riquier Productivity Index (RI) and Coefficient of Improvement (CI) for 2018 and 2019 Cropping Seasons

Cropping Seasons	Actual Productivity		Potential Productivity		Coefficient of Improvement (CI)
	Rating	Class	Rating	Class	(%)
2018	59	Good	38	Good	0.64
2019	38	Good	40	Good	1.07

Relationship between Grain Yield of Soyabean and Riquier Productivity Index

Results of the correlation and regression analyses between grain yield of Soyabean and Riquier productivity in 2018 and 2019 are presented in Tables 5 and 6. Correlation analyses between grain yield of Soyabean and Riquier productivity values showed negative insignificant ($r = -0.462$, $p = 0.131$)in 2018 while that of 2019 indicated positive correlation ($r = 0.569$, $p = 0.027$) at $P<0.05$ under the various treatment combinations. These relationships showed that the grain yield of Soyabean increased with insignificant increase in soil productivity in 2018 and significantly increased in 2019 cropping season. This means that grain yield of maize increased with increase in the soil productivity. Regression did not fits the data as coefficients of determination (R^2) were not significant ($R^2 = 0.213$) and ($R^2 = 0.324$) for 2018 and 2019 respectively, while regression models were ($Y = 2.944 + 2.856 X$) and ($Y = - 0.886 + 1.990 X$) for 2018 and 2019, respectively.These relationships showed that the grain yield of Soyabean increased with insignificant increase in soil productivity.

The result further showed that RI model could explain about 56 % of soyabean grain yield variation in the second season of the study site. The RI could explain to a greater extent yield variations and give more reliable results in the Makurdi agro ecological area as also reported by Agber (2011), Agber and Ali (2012). The result implies that difference in soil characteristics as a result of soil amendments and tillage practices could affect soil productivity and eventually grain yield of crop.

Table 5. Correlation Coefficient (r) and P-Values between Grain Yield of Soyabean and Riquier Productivity Index (RI)

Relationships	Corr. Coeff. (r)	P-value
2018		
Grain Yield vs. RI	- 0.462	0.13
2019		
Grain Yield vs. RI	0.569	0.027

Table 6. Regression Model and Coefficient of Determination (R^2) between Grain Yield (GY) of Soyabean and Riquier Productivity Index (RI)

Relationships	Regression model	(R^2)	p-value
2018			
GY vs. RI	Y= 2.944 – 2.856 X	0.213	0.13
2019			
GY vs. RI	Y= -0.886 + 1.990 X	0.324	0.53

Conclusion

The study has shown that application of 10 t/ha poultry manure, 15 t/ha moringa and SSP at 120 kg/ha at various treatment combinations improved the fertility status of the soil compared to control plots. The higher RI values of the soil properties observed under poultry manure and moringa treatment combinations reflected increased in soil productivity and therefore, increase the precision of the model. The RI coefficient of improvement values of 0.64 and 1.07 % obtained in 2018 and 2019 respectively indicated improvement or maintenance of soil productivity capacity of the land.

REFERENCES

Agber, P.I. (2011). Testing the effectiveness of soil productivity assessment models in Makurdi, Benue State, Nigeria. Ph.D Thesis, Department of Soil Science, University of Agriculture, Makurdi. Pp. 25 – 45.

Agber. P. I and Ali, A. (2012). Evaluation of the productivity of soils in Makurdi, Southern Guinea Savanna, Nigeria using Riquier index. *Journal of Enviromental Science and Water Resources*, 1 (5): 100-104.

Agber, P.I and Anjembe, B.C. (2012). Testing the effectivness of soil productivity indx (PI) model for selected soils in Makurdi. Nigeria. *ARPN Journal of Agricultural and Biological Science*, 7 (2): 227-232.

ASAE. (1985). Erosion and Soil Productivity. Proceedings of National Symposium. Erosion and Productivity New Orleans LA 10-11 Dec. 1984. America Society of Agriculture Engineering, St. Joseph, M, 149085. Pp. 80 – 89.

De La Rosa, Cardona, D.F., and Almorza, J. (1982). Crop yield predictions based on properties of soils in Sevilla, Spain. *Geoderma*, 25: 267-274.

Follet, R. F., and Stewart, B.A. (1985). Soil Erosion and Crop Production. *America Society of Agronomy*. Madison. Wisconsin, USA. Pp. 261 – 274.

Gantzer, C.J., and McCarty, T.R. (1987). Predicting corn yields on a clay pan using a soil productivity index. *Trans America Society of Agricultural Engineering*, 30: 1347-1352.

Idoga, S., and Ejembi, E.P. (2003). Socio-Economic impact of soil erosion in Benue State: Implication for agricultural and educational development. *Journal of Educational and Vocational Research*, 7 (1 and 2): 95 – 102.

Kiniry, L.M., Scrivener, C.L., and Keener, M.E. (1983). A soil productivity index based on water depletion and root growth. Research Bulletin 105, Colombia University of Missouri. P. 89.

Lal, R. (1990), Soil Erosion and Land Degradation. The Global risks. In: R. Lal and B.W. Stewart (eds). Soil Degradation. *Advances in Agronomy*, 11: 1290172.

Lal, R. (1994). Soil erosion by wind water: Problems and prospects In R. Lal (ed.) Soil Erosion Research Methods. 2nd edition. USA: Soil and Water Conservation Society and St. Luice Press. Pp. 78 – 90.

Lal, R. and Pierce, F.J. (1991). The vanishing resources. In: Lal, R. and F.J. Pierce, (eds.) Soil management for sustainability. Soil and Water

Conservation. IOWA: Soil and Water conservation Society. Pp. 1 – 5.

Mbagwu, J.S.C, Lal, R., and Scott, J.W. (1984). Effects of artificial desurfacing of alfisols and ultisols in southern Nigeria II. Changes in soil physical properties. *Soil Science Society of America Journal*, 48: 835-837.

Ngwu, O.E., Obi, M. E., and Mbagwu, J.S.C. (2005). Effects of desurfacing on soil and maize yield. *Nigeria Journal of Soil Science*, 15 (2): 148-150.

Nwite, J.N., and Nnoke, F.N. (2005). Productivity assessment of floodplain in Abakaliki, south east Nigeria. *Nigeria Journal of Soil Science*, 15 (2): 51-56.

Piccolo, A.G. Pietrammelara, J.S., Mbagwu, C. (1997). Reduction in soil loss from erosion susceptible soils amended with humic substances from oxidized coal. *Soil Technology*, 10: 235 - 245.

Riquier, J., Cornet, J.P., and Braniao, D. (1970). A new system of soil appraisal in terms of actual and potential productivity. 1st Appoxi. World Soil Resaerch, FAO. P. 44.

Udo, E.J., Ibia, T.O., Ogunwale, J.A., Ano, A.O., and Esu, I.E. (2009). Manual of Soil, Plant and Water Analysis, 1st Edition. Sidon Book Ltd, Lagos. Pp. 17 – 76.

Williams, J, R., Dyke, P.T., and Jones, C.A. (1983). EPIC-A model for assessing the effect of erosion on soil productivity. Proceedings of 3rd International Conference on state of the art in ecology Modeling May 24-28 Fort Collins Co, USA. Pp. 315 – 321.