Colloquia Series
Available online at www.publishingrealtime.com
Publishing Real Time
Colloquia SSSN 44 (2020)
Proceedings of the 44th Conference of Soil Science Society of Nigeria on Climate-smart soil management, soil health/quality and land management: synergies for sustainable ecosystem services

Degradation assessment of fallowed and cultivated soils of Teaching and Research Farm, Federal University Dutse, Jigawa State.

***Awwal, A.Y.[1], Onokebhagbe, V.O.[2,] and Adegboye K.A.[1]**

[1]Department of Soil Science, Ahmadu Bello University, Zaria
[2]Department of Soil Science, Federal University Dutse

Abstract

Fallowed and cultivated soils of Teaching and Research Farm, Federal University Dutse (TRF, FUD) were investigated to compare their degradation rates. Representative soil samples from farmlands were collected from the surface (0-15 cm) and sub-surface (16-30 cm) soil depths from cultivated (millet and sorghum farms) and fallowed (Block A and Block B) lands. The soil's physical and chemical properties were investigated in the field and laboratory. Data collected were subjected to descriptive statistics and soil degradation assessment was done following standard procedures. The results revealed that the fallowed soils were moderately degraded (44.44%), while cultivated soils were highly degraded (52.78%). Physical and biological degradation was more pronounced on the cultivated soils, which was attributed to the effect of cultivation. However, both soils were degraded which indicated that fallow methods or time was still insufficient. Conservation tillage improved bush fallowing mechanisms such as leguminous fallow and proper management of organic wastes. These were suggested as management practices that could replenish the nutritional status of both soils.

Keywords: Cultivated; Chemical analysis; Fallowed; Physical analysis; Degradation

Corresponding Author's E-mail Address: awwalyasin313@gmail.com: Phone: +2348052614007
https://doi.org/10.36265/colsssn.2020.4010

Peer-review under responsibility of 44th SSSN Conference LoC2020.

1.0. Introduction

The land is an important natural resource, and its maintenance in good health is much needed for meeting the increasing demand for food, fiber, fodder, and fuel. It assumes greater significance in the present situation wherein the scope for further extension of cultivation is very limited (Mohammad and Mazer, 2014). In the last two decades, assessments of soil quality and measurement of the impact of management practices aimed at improving it have been the topic of considerable discussion in agricultural circles (Andrews *et al.*, 2004). Land degradation will remain an important global issue for the 21st century because of its adverse impact on agronomic productivity, the environment, and its effect on food security and the quality of life (Eswaran *et al*., 2001). On a global scale, it has been estimated that nearly 2 billion hectares of land are affected by human-induced soil degradation (UN, 2000). Due to the global dilemma that could result from the adverse effects of degradation, soil experts lay great emphasis on the importance of putting soil to its most suitable and sustainable use.

Land degradation is a complex term that may be physical; such as crusting, compaction, erosion, desertification, and environmental pollution; chemical, such as acidification, leaching, salinization, reduced cation exchange capacity (CEC) and reduced fertility; or biological, such as a reduction in total carbon (TC), soil biomass and soil biodiversity (Lal, 1997). Physical, chemical, and biological soil deterioration has already become a critical problem in many countries all over the world. In many parts of sub-Saharan Africa, fallow periods are being considerably reduced and farmers' increasingly extending cultivation to marginal lands susceptible to soil degradations. Therefore, improved land use management and soil conservation are urgently required to save the foundation that supplies food for present and future generations (FAO, 2000).

The land has been utilized intensively for all purposes at the expense of its suitability, thereby altering the natural ecological conservational balances in the landscape. Such imbalances pose great difficulty in soil productivity and food security (Senjobi, 2007). Without an insightful evaluation into the nutritional inventory of agricultural land resources, degradation is bound to set in; especially in the less resilient soils of the Savannah (Lal, 1997). The economic impact of soil degradation is extremely severe in densely populated sub-Saharan Africa (Lal, 1995). Its reclamation; where possible, is expensive to the peasant farmers who represent the higher proportion of food producers in Nigeria. Therefore, intensive and scientific investigation is the *sin qua non* to curbing this threat posed to food security. This research aimed to determine and compare the degradation indices of fallowed and cultivated soils on Teaching and Research Farm, Federal University Dutse, Jigawa state.

2.0 Materials and methods

The study was carried on fallowed and cultivated plots of Teaching and Research Farm, Federal University Dutse, Jigawa State, Nigeria; which is located between longitudes 11° 42' East and latitude 9° 23' North and longitudes 11° 70' East and latitude 9° 37' North (Figure 1). The studied areas comprised 50 hectares of cultivated and fallowed lands with flat to a nearly flat relief. The parent material in the study area is underlain by older granite and Oligocene (Ogezi, 2002). The average monthly temperature is between 30°C and 45°C and an annual rainfall of 743 mm

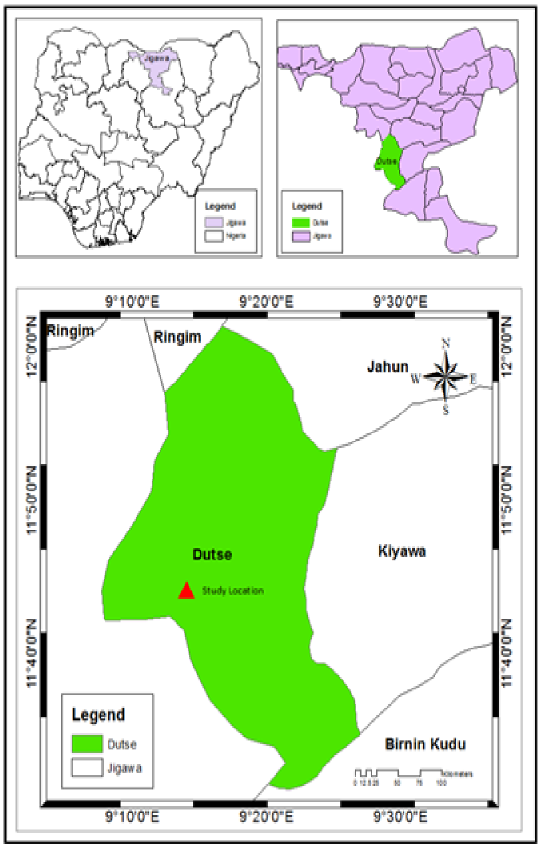

Figure 1: Map of Nigeria Showing Jigawa State, Dutse and the Study Location

(FUD Meteorological Stations, 2017). Staple crops grown on the cultivated soils included millet, guinea corn, onions, and sesame. The fallow soils were identified as field plots or blocks with signs of ridging and seeding beds without any crops planted for at least two years.

2.2 Soil Sampling and Laboratory Analyses

Two composite samples (each for disturbed and undisturbed soils) were randomly collected at two varying depths (0-15 cm and 16–30 cm). This was done for both cultivated and fallowed soils in the studied area respectively. The soil samples were labeled, air-dried, crushed, sieved through a 2 mm mesh, and subjected to various physical and chemical analyses. Particle size analysis was done following the standard procedures of Gee and Bauder, (1986). Bulk density was determined following the procedures outlined by Blake and Hartge, (1986). Soil pH was measured in a 1:2.5 soil-water ratio suspension. Organic carbon was estimated using the Walkley-Black method and the content of organic matter was obtained by multiplying organic carbon content by a factor of 1.724. Total nitrogen was analyzed using the Kjeldahl distillation method. The available phosphorus was determined by the Olsen method as described by Agbenin (1995). Exchangeable cations (Ca, Mg, K, Na) were determined by the NH_4oAC method as described by Agbenin (1995). Cation exchange capacity (CEC) was determined by the NH_4oAC extraction method of Rhoades (1982), base saturation percentage (BSP) and exchangeable sodium potential were duly computed.

2.3 Soil Degradation Assessment

The levels of degradation of soils were assessed using the standard indicators and criteria for land degradation assessment by the Global Assessment of Land Degradation as shown in Table 1 (GLASOD, 1998). Analytical data from each sample were placed in a degradation class by matching the soil characteristics with the land degradation indicators, while estimation of the overall degree of degradation was arrived at mathematically, using physical, chemical, and biological parameters as shown in equation 1. A

$$\text{Overall Degree of Degradation} = \frac{(\sum_{i}^{n} \text{degree of degradation of each quality}) \times 100}{\text{Max. degree of degradation} \times \text{number of qualities}} \quad ...1$$

value of 1 shows minimal degradation while 4 represents an extreme range of degradation.

2.4 *Statistical Analysis*

Data collected were subjected to descriptive statistics using Microsoft Excel version 2013. Mathematical estimation of the degree of degradation was carried using the degradation equation with Microsoft Excel.

3.0 Results and Discussion

3.1 Physical Degradation

Mean values of soil physical and chemical properties are summarized in Table 2 while degradation scores for each indicator and overall degradation rating are shown in Table 3. From Table 2, an average bulk density of 1.41 mg m^{-3} was obtained from fallowed soils of the study area and this ranged from none to slightly degraded concerning bulk density, while cultivated soils with an average value of 1.51 mgm^{-3} were moderately degraded. Bulk density of soil is a dynamic property that has effects on compaction, root growth, and water retention within the soil. Degradation of soils concerning bulk density entails its increase from its optimum of 1.40 mgm^{-3} and 1.60 mgm^{-3} for clayey and sandy soil respectively (Miller and Donahue, 1990). Researchers, such as Brady and Weil (2016), have linked bulk density to soil texture, structure, and organic components. Cultivation may have led to an increase in this property as cultivation has been noted to increase bulk density (Oyedele *et al.*, 2009).

Fallowed soils were moderately degraded in terms of permeability, while cultivated soils were highly degraded concerning the degradation scores as shown in Table 3. This meant that fallowed soils may retain more moisture than cultivated soils. There is an intrinsic relationship between bulk density and permeability (K_s). The permeability of soils is also affected by soil texture, structure, and porosity.

3.2 Chemical Degradation

Table 1: Indicators and Criteria for Land Degradation Assessment

Indicator	Degree of Degradation 1	2	3	4
Physical Degradation				
Soil bulk density (mg m^{-3})	<1.5	1.5-2.5	2.5-5	>5
Permeability (cm hr^{-1})	<1.25	1.25-5	5-10	>20
Chemical Degradation				
Content of N element (multiple decreases) N (%)	>0.13	0.13-0.10	0.10-0.08	>0.08
Content of Phosphorus Element (mg kg^{-1})	>8	8-7	7-6	<6
Content of Potassium Element (cmol (+) kg^{-1})	>0.16	0.16-0.14	0.14-0.12	<0.12
Content of ESP (increase by 1% of CEC)	<10	10-25	25-50	>50
Base saturation (decrease of Saturation in more than 50%	<2.5	2.5-5	5-10	>10
Excess salt (Salinization) (increase of conductivity mm ho cm^{-1} yr^{-1})	<2	2-3	3-5	>5
Biological Degradation				
Content of humus in soil (%)	>2.5	2.5-2.0	2.0-1.0	>1.0

Source: GLASOD, (1998); Snaking *et al*. (1996).
Key:

Class of Degradation	**Overall Degree of Degradation (%)**	**Description**
1	0-25	Non to slightly degraded soil
2	26 – 50	Moderately degraded soil
3	51 -75	Highly degraded soil
4	76 – 100	Very highly degraded soil

Table 2: Summary of Some Physical and Chemical Properties of the Studied Soils

Soil Properties	**Units**	**Fallow Soils**	**Cultivated Soils**
Sand	g kg^{-1}	750.7	751.0
Silt	"	111.3	109.2
Clay	"	138.0	139.8
Texture	-	LS	LS
Soil Bulk Density	mg m^{-3}	1.41	1.51
Permeability	cm hr^{-1}	4.3	5.6
Total N	g kg^{-1}	0.21	0.11
Available P	mg kg^{-1}	0.39	0.04
Exchangeable K	cmol (+) kg^{-1}	2.73	0.88
ESP	%	4.33	9.44
BS	"	82.2	69.2
EC	dS m^{-1}	0.01	0.10
Humus	%	1.03	0.71

Table 3: Degradation Scores for the Various Studied Soils

Indicator	Fallowed Soils	Cultivated Soils
Physical Degradation		
Soil bulk density (Mg m^{-3})	1.00	2.00
Permeability (cm hr^{-1})	2.00	3.00
Chemical Degradation		
Content of N element (multiple decrease) N (%)	2.00	2.00
Content of Phosphorus Element (mg kg^{-1})	4.00	4.00
Content of Potassium Element (cmol (+) kg^{-1})	1.00	1.00
Content of ESP (increase by 1% of CEC)	1.00	1.00
Base saturation (decrease of Saturation in more than 50%	1.00	1.00
Excess salt (Salinization) (an increase of conductivity mm ho cm^{-1} yr^{-1})	1.00	1.00
Biological Degradation		
Content of humus in soil (%)	3.00	4.00
Overall Degradation Index	44.44%	52.78%

In terms of chemical degradation, both fallowed and cultivated soils were moderately degraded to the content of nitrogen as shown in Table 3. The generally low nitrogen content may have been due to the high rate of N mineralization and loss of organic matter content in the soils as a result of high temperatures found in these regions (Juo *et al.*, 1974). To control the rate of nitrogen degradation and loss in these soils, the use of organic mulches and proper management practices such as discouraging the removal of crop residues (stubbles) by farmers should be employed.

Fallowed and cultivated soils were very highly degraded concerning the content of phosphorus. The generally low P status is explained in terms of low clay content noted in these soils and can as well be linked to low the organic matter content of the soils as shown by the low humus content in Table 2. Conversely, fallowed and cultivated soils were non to slightly degraded concerning the content of potassium element, ESP, BSP, and EC. Amongst others, this is a good indication that the soils had non to very slight salinity and sodicity threat.

3.4 Biological Degradation

In terms of humus content of the soils, fallowed soils were highly degraded, while cultivated soils were very highly degraded. Degradation and low humus content in savanna soils have been reported by several researchers (Jones and Wild, 1975; Esu *et al.,* 1987; Bownan e*t al.,* 1990; Raji *et al.,* 1995; Odunze, 1998; Maniyunda, 2012). However, the loss rate of humus is noted to be higher in cultivated soils than fallowed soils. This was largely based on the fact that cultivation accelerates the depletion of organic matter content in soils (Hilel 1980; Ashenafi *et al.,* 2010). To protect these soils from further biological degradation, conservation tillage and proper management of organic wastes should be employed.

3.5 Overall Degradation

The overall degradation rate indicates that fallowed soils were moderately degraded (44.44%), while cultivated soils were highly degraded (52.78%). This confirms several earlier reports that over cultivation may lead to depletion of soil qualities (Jones, 1971; Juo and Lal, 1976; Abdulahi and Lombin, 1978; Oyedele *et al.* 2009; Ande and Senjobi, 2014).

4.0 Conclusion and Recommendation

The study reveals that cultivated soils of Teaching and Research Farm, Federal University Dutse are more degraded than the fallowed soils. This might have been as a result of nutrient depletion associated with over-cultivation. Although evidence of degradation is manifest on both soils, the fallow method or period is still insufficient. Chemical and biological degradation is a result of soil fertility depletion and organic matter decline through exploitative cropping which could be ameliorated through improved nutrient management. Physical degradation involves soil deterioration in-situ, which is a result of improper management practices and requires a long time to ameliorate. Degradation for bulk density can be minimized by applying appropriate tillage practices. Bush following mechanisms together with other management practices such as mulching will go a long way to replenish the organic matter and nutrient status of the soils.

References

Abdullahi A. and Lombin G., (1978). Long term fertility studies at Samaru Nigeria. Comparative effectiveness of the separate and combined application of mineral fertilizers and farmyard manure in maintaining soil productivity under continuous cultivation in the savannah. Samaru misc, paper 75. Institute for Agric. Research ABU, Zaria, Nigeria.

Ande T. A. O., and Senjobi B. A. (2014). Comparison of Soil Quality Improvement under Different Fallow Types on Dystric Nitosols Derived from Sand Stone in South Western Nigeria*Science Research Agricultural Sciences*, 2014, 5, 1061-1068.

Andrews, S. S., Karlen, D. L., and Cambardella, C. A. (2004). The soil management assessment framework. *Soil Science Society of America Journal, 68*, 1945–1962.

Ashenafi A., Esayas, A. and Beyene, S. (2010). Characterizing soils of Delbo Wegene watershed, Wolaita Zone, Southern Ethiopia for planning appropriate land management. *Journal of Soil Science and Environmental Management*, 1 (8) 184-199.

Blake, G.R., and Hartge, (1986). Bulk density in Klute (eds). *Methods of soil analysis, part Physical, and mineralogical methods* 2nded. ASA, SSSA Madison, WI 377-382p.

Bowman R.A., Reeder J.D., and Lober R.W. 1990. Changes in soil properties in a central plain rangeland soil after 3, 20, and 60 years of cultivation. *Soil Science*. 150: 851-857.

Brady, N.C., and Weil, R.R. (2016). Nature and properties of soil 13th Edition, Macmillian Publishing Company, p 88.

Esu, I.E., Ibanga, I.J., and Ojanuga, A.G. (1987). Soil-landscape relationships in Keffi plains of northern Nigeria. *Samaru Journal of Agricultural Research*. 5(1&2):109-123.

Eswaran, H., R. Lal, and P.F. Reich. (2001). Land degradation: an overview. Natural Resources Conservation Service Soils, United States Department of Agriculture

FUD Meteorological Station (2017). Federal University Dutse, Jigawa State, Nigeria.

Gee, G.W., and J.W. Baudar. (1986). Particle size analysis. In: A. Klute ed. Methods of soil analysis. 2nd ed. No. 9 *ASA Inc. SSA. Inc*. Madison, Washington, D.C. pp. 383-409.

GLASOD, (1998). Global assessment of soil degradation. Guidelines for General Assessment of the status of Human-induced Soil Degradation. Wageningen (Netherlands) ISRIC and UNEP.

Hillel, D. (1980). Fundamentals of Soil Physics. Harcourt Brace Jovanovich publisher, Academic Press, Inc. San Diego. Pp. 74-79.

Jones, M.J., and Wild, A. (1975). Soils of the West African savanna. Tech. Common. SS Commonwealth Bureau of Soils, Harpenden, U.K.

Jones, M.J., and Wild, A. (1975). Soils of the West African savanna. Tech. Common. SS Commonwealth Bureau of Soils, Harpenden, U.K.

Juo, A.S.R., Moormann, F.R., and Maduakor, H.O. (1974). Forms and pedogenic distribution of extractable iron and aluminum in selected soils of Nigeria. *Geoderma* 11:167-179.

Lal R. (1997). Degradation and Resilience of Soils. Phil. Trans. R. Soc. Lond. B (1997) 352, The Royal Society. Printed in Great Britain.

Lal, R. (1995) Erosion-crop productivity relationships for soils of Africa. *Soil Sci*. *Soc*. *Am*. J. *59*, 661-667.

Maniyunda L.M. (2012). Pedogenesis of a Lithosequence in the Northern Guinea Savanna of Kaduna State, Nigeria. Ph.D. Dissertation. Ahmadu Bello University Zaria, Nigeria.

Microsoft Excel Version 2013. Microsoft Cooperation (2013).

Miller, R.W., and Donahue, R.L. (1990). Soils: An introduction to soils and plant growth. Patience hall, New Delhi, India. 768 pp.

Mohammad S.N. and Mazer M. (2014). Land Suitability Analysis for Sustainable Agricultural Land Use Planning in Bulandshahr District of Uttar Pradesh. *International Journal of Scientific and Research Publications.* 4(9) ISSN 2250-3153

Odunze, A.C. (1998). Soil management strategy under continuous rainfed-irrigation agriculture. Proceedings of the 12th National Irrigation and Drainage Seminar. Irrigation in sustainable Agriculture. 14 -16th April 1998, IAR, ABU, Zaria, Nigeria. PP 178-186.

Ogezi, E.A. (2002). Geology. In Les Editions J.A. (ed). Africa Atlases. Atlas of Nigeria. 57 bis rue d'Auteuil, 75016 Paris – France. PP 60-61.

Oyedele D. J., Awotoye O. O., and Popoola S. E., (2009). Soil physical and chemical properties under continuous maize cultivation as influenced by hedgerow trees species on an alfisol in South-Western Nigeria. *African Journal of Agricultural Research* Vol. 4 (7), pp. 736-739.

Raji, B. A. (1995). Pedogenesis of ancient dune soils in the Sokoto sedimentary basin, North-Western Nigeria, unpublished. Ph.D. thesis ABU Zaria, Nigeria. 194 PP.

Rhoades, J.D. (1982). Cation exchange capacity. In-Page, A.L., Miller, R.H. and Keeney, D.R. (eds). *Methods of Soil Analysis.* Part 2 Agron 9. Madison WI. PP 149-157.

Senjobi, B. A.; Adeokun, O. A.; Dada, O. A. and Ogunkunle A. O. (2007). Influence of Traditional Farming Practices on Soil Productive Potentials in Ago-Iwoye Enclave, Ogun State, Nigeria. Journal of Environmental Extension, Vol. 6: 64-70, University of Ibadan, Ibadan, Nigeria

Snaking, V. V., P. P. Krechetor, T. A. Kuzovnikova, I. O. Alyabina, A. F. Gurov, A. V. Stepichev (1996). The System of assessment of soil degradation. Soil Technology. 8: 331 – 343.

UN (2000) UN Secretary General's Report A/504/2000 Chapter C. Defending the Soil.