



Infiltration Characteristics of Soils in Owerri, Imo State, Southeastern Nigeria under Four Selected Land Uses

U. O. Onyegbule^{1*}, E. O. Azu, Donatus² and U. N. Akagha¹

¹*Department of Agricultural Technology, Imo State Polytechnic, Umuagwo-Ohaji, Nigeria.*

²*Department of Horticulture and Landscape Technology, Akanu Ibiam Federal Polytechnic, Unwana, Ebonyi State, Nigeria.*

Authors' contributions

This work was carried out in collaboration between all authors. Author UOO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author EOAD managed the analyses of the study. Author UNA managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ASRJ/2018/v1i13686

Editor(s):

- (1) Dr. Jesus Soria-Ruiz, Professor, National Institute of Research for Forestry, Agricultural and Livestock, Mexico.
(2) Dr. Salem Abogllila, Professor, Faculty of Geochemistry & Environmental Chemistry, Azzaytuna University, Libya.

Reviewers:

- (1) Jakub Nieć, University of Life Sciences in Poznan, Poland.
(2) Alaa Nabil El-Hazek, Benha University, Egypt.

Complete Peer review History: <http://www.sciedomain.org/review-history/25934>

Original Research Article

Received 3rd May 2018
Accepted 2nd August 2018
Published 17th August 2018

ABSTRACT

Knowledge of the infiltration characteristics of soils could play a significant role in the choice of appropriate soil management practices that is capable of alleviating the production constraints of soils. The infiltration characteristics of soils in Owerri under four different lands uses viz: secondary forest, plantain plantation, continuously cultivated land and the grazing land was investigated with the aid of a double ring infiltrometer. Results showed that the secondary forest, plantain plantation, continuously cultivated land, as well as the grazing land all, recorded low infiltration rates of 26.54 mm/hr, 26.0 mm/hr, 18.87/hr and 21.35 mm/hr respectively. There were also significant differences in the soil physical and chemical properties notably the hydraulic conductivity, bulk density, water content, organic matter, total nitrogen, as well as available phosphorus ($P < 0.05$). The results obtained suggest that the inherent land uses in the area affected the infiltration of water as well as

*Corresponding author: E-mail: Uzomaonyegbule1984@gmail.com;

the soil quality indices. Land use practices that will improve the organic matter, as well as the water transmissivity of the soils such as conservation tillage, fallowing and controlled grazing, should be adopted and sustained.

Keywords: Infiltration rate; accumulated infiltration; land use and soil properties.

1. INTRODUCTION

Infiltration is the movement of water from the surface by downward or gravitational flow [1]. The rate at which this occurs is referred to as the infiltration rate. Till date infiltration remains one of the most important soil parameters as it contributes to a number of soil processes such as in organic matter decomposition, watershed modelling for the prediction of surface runoff [2]. Similarly, in the planning of water conservation techniques and land evaluation for effluent water disposal, the role of infiltration cannot be overemphasized [3]. A number of soil properties, land use patterns, initial moisture content as well as the rainfall pattern are some of the factors that affect the infiltration rate of an area.

When land is subjected to certain uses there is an accompanying change in the intrinsic properties of the soil and this alters the hydrological balance of the soil [1]. Reports indicate that different land use types influence the hydrologic balance of the soil by altering its intrinsic properties [4]. These land uses often result in altering the texture, structure as well as the pore spaces of the soil. For instance, deforestation often results in soil sealing, and this reduces the volume of water that infiltrates into the soil resulting in increased runoff [5]. The increased runoff results to erosion and decline in productivity as the water which would have been used in organic matter decomposition and mineralization will now flow as runoff. The runoff most of the time carries dissolved nutrients. Well, structured soils have optimum infiltration rate at varying antecedent moisture levels. The disruption of the pore spaces as a result of land use practices sometimes outweighs the geno form traits (characteristics inherent from parent materials) in determining water movements [6].

The pattern of land use in Owerri, Imo state has not only affected the soil quality indices but has equally affected the productivity of agroecosystems [1]. As a result of urbanization, fallowed land is being cleared and converted to other imaginary uses. Kigne [7] had earlier stated

that urbanization is the most forceful of all the changes that affect the hydrology of an area; this forcefully brings about a decrease in the volume of water that percolates the soil as the excess flow becomes runoff. Despite the general recognition of the threats of runoff, low productivity, little studies have been made to determine the effect of the various land uses on the infiltration rates of the soils and the relationship between these infiltration rates and some soil properties. Therefore this study was carried out to determine the infiltration rate and the relationship between the infiltration rate and some soil properties in selected soils of Imo State.

2. MATERIALS AND METHODS

2.1 Study Location

The study was undertaken at the research and demonstration farms of the Imo state University Owerri and in a grazing land in Obinze all in Owerri.

Owerri is located between latitude 5°25'10" N and 5°30'15" and longitude 7°10'E and 7°40'E. It lies within the humid tropical climate with annual rainfall and temperature of over 2000 mm and 20°C respectively [8].

2.2 Land Description

The common land use system in the area is arable farmland planted with maize, cassava and yam. There are also oil palms and banana plantations in the area and the soils are managed by the use of mineral fertilizer and livestock wastes. Four areas under different land use namely a secondary forest of more than 15 years, a plantain plantation of more than 5 years old, a continuously cultivated land as well as a grazing land served as the experimental treatment.

2.3 Sample Collection and Laboratory Analysis

For the purpose of soil sample collection, profile pits were dug in three replications in each of the

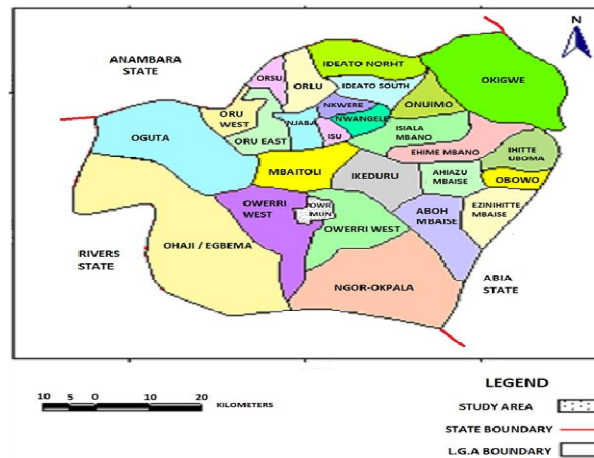


Fig. 1. Map of Imo state showing the study locations

different land use systems. Four samples from distinguished soil horizons were collected from each of the profile pit, giving a total of 48 observational units. These samples were prepared and analyzed using standard laboratory procedures.

The particle size distributions were determined by the hydrometer method [9], bulk density was determined by the core method [10], saturated hydraulic conductivity was determined by the constant head method, the organic carbon was determined by the wet oxidation method while the organic matter was calculated by a factor of 1.72 [11]. The infiltration rate was determined with the aid of a double ring infiltrometer as described by [12]. The slope of the graph of infiltration against time was taken as the infiltration rate of the land uses. The soil properties among the different land uses were compared using a two-way analysis of variance [13]. The mean and coefficients of variations among samples were determined. Linear

correlation between the infiltration rate and selected soil properties were established.

3. RESULTS AND DISCUSSION

3.1 Physical and Chemical Properties of the Soils from Different Land Use Systems

The physical and chemical properties of the soils from different land use systems are presented in Table 1. Results showed that variability in sand, silt and clay among different land use systems were observed, but these variations were not statistically significant, except in land under grazing where these textural indicators were shown a significant difference ($P < 0.05$).

The percentage clay was higher in the secondary forest and in the grazing land. The increased clay content in the secondary forest compared to the other land use. The increased clay content in the secondary forest compared to the other land use systems coupled with the dense vegetal surface

Table 1. Mean soil physical and chemical properties of the four land uses

Soil properties	Continuously cultivated land	Plantain plantation	Secondary forest	Grazing land	Coefficient of variation
%Sand	83.2 ^a	83.0 ^a	71.83 ^a	76.9 ^b	1.52
%Silt	8.71 ^a	10.8 ^a	12.13 ^a	7.2 ^d	13.71
%Clay	7.9 ^b	6.01 ^b	16.05 ^a	16.01 ^a	24.06
BDg/cm ³	1.40 ^b	1.26 ^c	1.10 ^d	1.54 ^a	2.8
%Porosity	47.0 ^c	53.34 ^b	58.3 ^a	41.8 ^d	2.68
%Moisture	6.72 ^c	9.61 ^b	12.1 ^a	5.00 ^d	4.4
%Ksat(cm/hr)	0.23 ^c	0.25 ^b	0.35 ^a	0.22 ^d	5.77
%O.M	1.24 ^d	1.60 ^c	2.93 ^a	2.46 ^b	4.14
TotalN%	0.04 ^d	0.06 ^c	0.16 ^a	0.09 ^b	10.9
Av.P	2.42 ^c	3.74 ^b	4.54 ^a	4.41 ^a	14.8

must have resulted in the increased organic matter. The hydraulic conductivity in Table 1 was also higher in the secondary forest compared to the other land uses. Variability in on the percent total nitrogen was observed among the different land use type and these differences were significant (P<0.5). The order of the occurrence of the nitrogen in relation to land use is: secondary forest (0.16)> grazing land (0.09)> plantain plantation (0.06)> continuously cultivated land (0.04). The highest amount of nitrogen in the secondary forest can be a reflection of the larger amount of organic matter due to higher litterfall and subsequent mineralization to release nitrogen [14]. In contrast, low level of nitrogen in continuously cultivated land may be attributed to greater rate of organic matter loss due to plant removal and high leaching of nitrate from such soils. A significant variation in the amount of phosphorus in relation to land use type was observed. Generally, soil of secondary forest had the highest amount of phosphorus in respect to soils of other land use types.

3.2 Average Infiltration Rates of the Soils from Different Land Use Systems

The results of the measured infiltration against time and accumulated infiltration are presented in Tables 2, 3, 4 and 5 while the graphical representation of the infiltration rate against time and accumulated infiltration against time are presented in Figs. 1 and 2. Results showed that irrespective of land use type, the rate of

infiltration increased with time, but the accumulated infiltration rate decreased with time. The results showed that the Secondary forest, Grazing land, Plantain plantation and the Continuously cultivated land had average steady state infiltration rates of 26.54, 21.35, 26.0 and 18.87 mm/hr respectively and accumulated infiltration rate of 66.40, 48.52, 60.89 and 45.77 mm in that order (Tables 2, 3, 4 and 5). It was observed that soil from secondary forest had the highest rate of infiltration and accumulation, followed by soil from plantain plantation. The high infiltration rate observed in the secondary forest compared to the other sites can be attributed to the presence of dense vegetal cover and the activities of microorganisms. The loosening of surface soils arising from the spread of lateral roots creates channels in the soil.

[15] had observed that the presence of dense vegetal cover on the surface increases the infiltration rate of soils. The findings of these research concurred with the position of [15]. The low accumulated filtration rate of 45.77 mm/hr observed in the soil under continuously cultivated land could be attributed to the low organic matter occasioned by the continuous cultivation. The continuous cultivation, as well as the low organic matter witnessed in the site coupled with the high bulk density in Table 3, may have contributed to the low infiltration rate value obtained [16] had earlier stated that long-term decrease in organic matter decreases the infiltration rate and thus the accumulated infiltration rate of soils.

Table 2. Average infiltration rate for the grazing land

Interval minutes	Time (min)	Time (hrs)	Water intake (mm)	Infiltration rate IR (mm/hr)	Acc. Infil AI (mm)
0	0	0	0	0	0
2	2	0.03	3.4	113	3.4
2	4	0.07	3.9	55.5	7.3
3	7	0.12	4.3	35.8	11.6
3	10	0.17	4.5	26.4	16.1
5	15	0.24	6	25	22.1
5	20	0.33	5.7	17.2	27.8
5	25	0.41	5.8	14.1	33.6
5	30	0.50	5.9	11.8	39.5
10	40	0.66	7.0	10.6	46.5
10	50	0.83	7.4	8.9	53.9
15	65	1.08	9.8	8.5	63.7
15	80	1.33	10.2	7.6	73.9
20	100	1.66	12.4	7.4	86.3
20	120	2.00	12.5	6.2	98.8
30	150	2.50	14.1	5.6	112.9
30	180	3.00	14.4	4.8	127.3
Mean	52.82	0.88	7.48	21.35	48.52

Table 3. Average infiltration rate for continuously cultivated land

Interval minutes	Time (min)	Time (hrs)	Water intake (mm)	Infiltration rate IR (mm/hr)	Acc. Infil AI (mm)
0	0	0	-	0	0
2	2	0.03	3.0	100	3
2	4	0.07	3.1	44.2	6.1
3	7	0.12	3.6	30.0	9.7
3	10	0.17	3.5	25	13.2
5	15	0.24	4.3	17.9	17.5
5	20	0.33	4.5	13.6	22
5	25	0.41	4.7	11.4	26.5
5	30	0.50	5.3	10.6	31.2
10	40	0.66	7	9.8	38.2
10	50	0.83	9.1	10.9	47.3
15	65	1.08	11.6	10.7	58.9
15	80	1.33	12.4	9.3	71.3
20	100	1.66	14.3	8.6	85.6
20	120	2.00	14.4	7.2	100
30	150	2.50	15.8	6.3	115.8
30	180	3.00	16.0	5.3	131.8
Mean	52.82	0.89	7.80	18.87	45.77

Table 4. Average infiltration rate for the plantain plantation

Interval minutes	Time (min)	Time (hrs)	Water intake (mm)	Infiltration rate IR (mm/hr)	Acc. Infil AI (mm)
0	0	0	-	-	-
2	2	0.03	4.2	140	4.2
2	4	0.07	4.6	65.7	8.8
3	7	0.12	5.4	45.0	14.2
3	10	0.17	5.2	30.5	19.4
5	15	0.24	6.6	27.5	26
5	20	0.33	7.1	21.5	33.1
5	35	0.41	7.0	17.0	40.1
5	30	0.50	7.1	14.2	47.2
10	40	0.66	10.9	16.5	58.1
10	50	0.83	11.5	13.8	69.6
15	65	1.08	13.2	12.2	82.8
15	80	1.33	13.0	9.7	95.8
20	100	1.66	14.5	8.7	110.3
20	120	2.00	14.9	7.4	125
30	150	2.50	16.8	6.7	141.8
30	180	3.00	16.9	5.6	158.7
Mean	52.82	0.89	8.58	26.0	60.89

Similarly, the static load, as well as the antecedent increase in bulk density as a result of compaction on the grazing land, led to the low infiltration rate observed in the site. Increased bulk density decreases the soils pore spaces that transmit water. Generally, the infiltration rates of the soils were low compared to the findings of

[1]. The infiltration relationships with selected soil properties indicated that the texture of the soils had little effect on the infiltration rate of the soils. [16] had earlier stated that the influence of texture on water infiltration predominates other factors, but this was not consistent with the findings of this research. This inconsistency can

be due to the fact that the soil samples used in this study were mostly sandy and hence, the effect of texture was not significant in influencing the infiltration properties of the soils. This study has shown that apart from texture, land use type also has a considerable effect on the infiltration properties of soils.

Table 5. Average infiltration rate for the secondary forest

Interval minutes	Time (min)	Time (hrs)	Water intake (mm)	Infiltration rate IR (mm/hr)	Acc. Infil AI (mm)
0	-	-	-	-	-
2	2	0.03	4.1	136.6	4.1
2	4	0.07	4.3	61.4	8.4
3	7	0.12	5.1	42.5	13.5
3	10	0.17	5.6	32.9	19.1
5	15	0.24	6.7	27.9	25.8
5	20	0.33	6.8	20.6	32.6
5	25	0.41	7.4	18.0	40.0
5	30	0.50	8.0	16.0	48.0
10	40	0.66	13.0	19.6	61.0
10	50	0.83	13.6	16.3	74.6
15	65	1.08	15.3	14.1	89.9
15	80	1.33	17.1	12.8	107
20	100	1.66	18.1	10.9	125.1
20	120	2.00	16.3	8.1	141.4
30	150	2.50	18.4	7.3	159.8
30	180	3.00	18.7	6.2	178.5
Mean	52.82	0.89	10.50	26.54	66.40

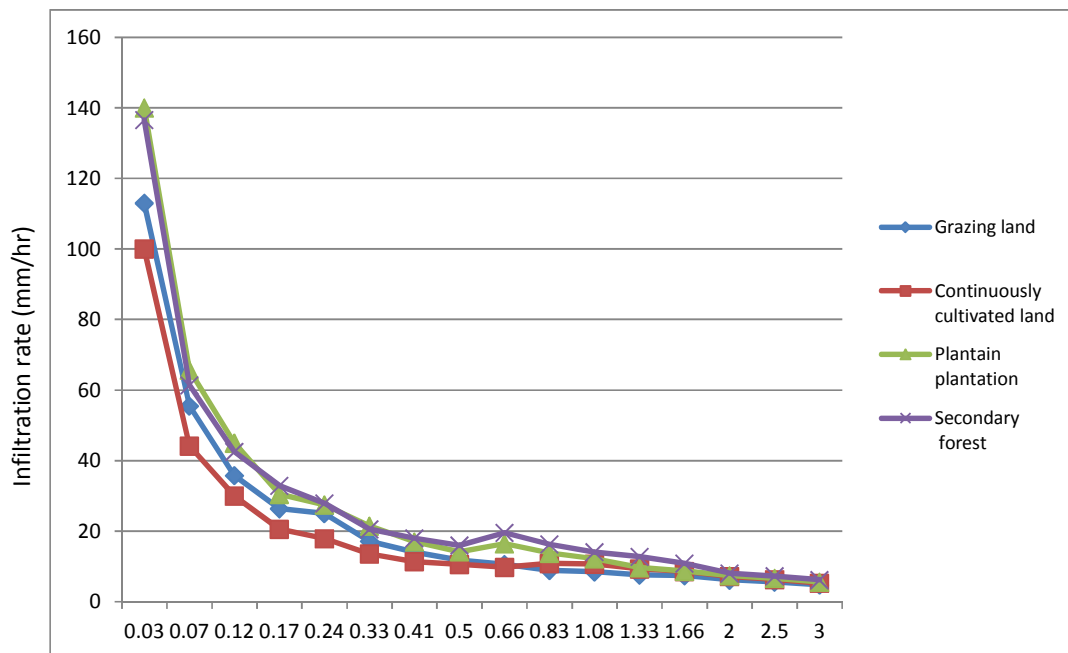


Fig. 1. Infiltration rate of the soils under different land use types

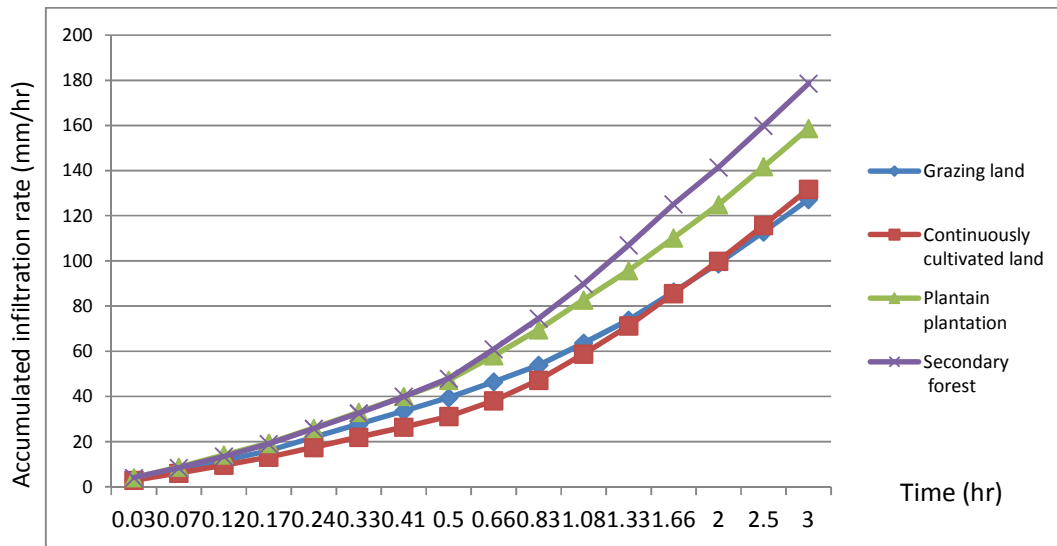


Fig. 2. Accumulated infiltration rate of the soils under different land use types

4. CONCLUSION

Soil water relations especially the infiltration properties provide an important index in the assessment of the soil quality in terms of the physical, biological and fertility properties. The infiltration characteristics of soils of contrasting land use type in Owerri Imo state Nigeria showed that soil from secondary forest followed by soil from plantain plantation showed better infiltration rate and accumulated infiltration rate compared to other land use systems investigated. Land under continuous cultivation and grazing had the least infiltration rate and accumulated infiltration rate. Thus, land use practices that will improve the infiltration rates of the soils such as conservation tillage, fallowing, mulching, minimal grazing should be adopted in order to improve the soils infiltrability, greater microbial activity as well as well as crop productivity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Osuji GE, Okon MA, Chukwuma MC, Nwarie II. Infiltration characteristics of soils under selected land use practices in Owerri South Eastern Nigeria. *World Journal of Agricultural Science*. 2011;6(b): 322-326.
2. Franzluebbers AJ. Water infiltration and soil structure related to organic matter and its stratification with depth. *Soil and Tillage Research*. 2002;66(2002):197-205.
3. Mbagwu JSC. Saturated hydraulic conductivity in relation to physical properties of soils in the Nsukka plains of south eastern part of Nigeria. *Geoderma*. 1995;68:51-56.
4. Lee KE, Foster RC. Soil fauna and structure. *Australian Journal of Soil Research*. 1991;29(6):745-775.
5. Drewry JJ, Paton RJ. Soil quality, cattle grazing of a winter fed brassica crop. *Australian Journal of Soil Research*. 2006;43:525-531.
6. Schwartz RC, Eveth SR, Unger PW. Soil hydraulic properties of cropland compared with a reestablished and native grassland. *Geoderma*. 2003;116:47-60.
7. Kigne JW. Salinization in irrigated agriculture in Pakistan, mistaken predictions. *Water Policy*. 2006;8:325-338.
8. Nigeria Meteorological Agency. Owerri weather data. NIMETH Office, Sam Mbakwe Cargo Airport Owerri Imo State; 2012.
9. Benton, Jones J. Jr. Laboratory guide for conducting soil test and plant analysis. CRC Press Boca Raton, Washington DC; 2001.
10. Carter MR, Gregorich EG. Soil sampling and methods of analysis 2nd (ed). Can Soc. Soil Sci. 2008;1224.
11. Nelson DN, Sommers LE. Total nitrogen, organic carbon and matter. In methods of

- soil analysis part 2. Amer. Soc. of Agronomy DM. Madison. 1982;30-32.
12. American Society for Testing and Materials. Methods of soil analysis. West Conshohocken, P.A, USA; 2003.
 13. Wahua TA. Applied statics for scientific studies. Africa-link Books; 1999.
 14. Brady NC, Weil RR. The nature and properties of soil. 13th Edn, Prentice Hall Inc. New Jersey; 2008.
 15. Sharma RK. Hydrology and water management principles: New Delhi. Manpat Rai Publication; 2000.
 16. Igwe CA. Soil physical properties under different management systems and organic matter effects on soil moisture along a soil catena in southeastern Nigeria. Journal of Tropical and Subtropical Agroecosystems; 2005.

© 2018 Onyegbule et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
<http://www.sciencedomain.org/review-history/25934>