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Steady state infiltration rate studies of lower Loko soils, Adamawa state, north east Nigeria

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ABSTRACT

The study was conducted at Lower Loko west of song local Government, Adamawa state. Infiltration, bulk density, and some physicochemical analysis were carried out on the five sites, designated as site 1A and B, site 2A and B, site 3A and B, site 4A and B and site 5A and B, based on the preliminary survey to characterize the steady state infiltration rate. The study confirmed infiltration variability in the area both within the sites and across the sites. The soils are characterized by low to moderately rapid steady state infiltration rate range from 4.98 $cmhr^{-1}$ to 11.61 $cmhr^{-1}$ for all the five sites with the cumulative infiltration range from 1.00 $cmhr^{-1}$ to 6.58 $cmhr^{-1}$ on the average for all the five sites in 3hours of infiltration. Variability was influenced by differences in the texture, bulk density and water holding capacity. Moreover, improved infiltration, reduced erosion menace in low steady state infiltration sites. Flooding in the lake, use of integrated nutrient management on the fields and construction of drainages in the area is suggested.

INTRODUCTION

Vast majority of earth's water resources are salt water, with only 2.5 % being fresh water. Approximately 70 % of the fresh water available on the planet equivalent to only 0.7 % of total water resource worldwide is available for consumption. From this 0.7%, roughly 87 % is for agricultural purposes (Parry 2007). According to the comprehensive assessment, one out of three people in the world are facing water shortages (Parry 2007). Around 1.2 billon people or almost one fifth world's population live in the areas of physical scarcity of water while another 1.6 billion people, or almost one fourth of the world population live in developing country that lack the necessary infrastructure to take water from river and aquifers known as an economic water shortage (UNEP 2002). Water is one of the growth factor limiting plants not only in arid and semi-arid environment where total crop needs usually exceed water supply, but also in the humid environment where poor rainfall distribution and low moisture availability to plants brings about water stress. Therefore, a good water management practice is important not only in arid and semi-arid environment with precipitation limitation but even in areas with poor distribution properties levels and degradation effect of soil and water erosion (Morgan 2005).

In recent years, Nigeria had experienced severe flooding especially along the major rivers of Niger and Benue (Yamusa et al. 2015). Similarly the negative consequence of drought and desertification is being experienced in the chad Basin perhaps due to anthropogenic factors and general climate change. Thus, making water management is a critical and relevant in agricultural production in Nigeria and Savanna region in particular (Salako 2003). Deterioration of soil physical condition coupled with erratic and heavy precipitation levels have in recent years escalated the incessant flooding in the area. Negative consequences on water resource management with crop production generally have been reported (Salako 2003). Soil physical factors mostly responsible for the variations are texture, aggregate stability, dispersion coefficient of clay, bulk density and exchangeable sodium percentage (Mahendran and Mathan 1992). Knowledge of the soil factors and data at which different soils take water under different conditions

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Table 1. Soil Texture of the Study Area.

Site	Soil depth (cm)	%Sand	%Clay	%Silt	Textural class
1A	0-20	67.2	15.6	17.2	Sandy loam
	20-50	70.1	13.4	16.5	Sandy loam
1B	0-20	65.3	17.1	17.6	Sandy loam
	20-50	66.1	14.7	19.2	Sandy loam
2A	0-20	58.3	18.3	23.4	Sandy loam
	20-50	60.1	17.5	22.4	Sandy loam
2B	0-20	56.3	20.3	23.4	Sandy loam
	20-50	55.7	19.9	24.4	Sandy loam
3A	0-20	61.2	15.8	23	Sandy loam
	20-50	60.8	19.4	19.8	Sandy loam
3B	0-20	65.6	14.6	19.8	Sandy loam
	20-50	68.8	21.9	9.3	Sandy clay loam
4A	0-20	60.4	26.7	12.9	Sandy clay loam
	20-50	57.1	25.8	17.1	Sandy clay loam
4B	0-20	60.1	20.3	19.6	Sandy loam
	20-50	68.8	17.6	13.6	Sandy Loam
5A	0-20	67.5	19.8	12.7	Sandy loam
	20-50	69.1	23	7.9	Sandy clay loam
5B	0-20	70.1	20.1	9.8	Sandy loam
	20-50	68.3	22.3	9.4	Sandy clay loam

is a good basis for planning water management budgets (Michael 1999). Infiltration of water into the soil is the rate at which water percolates into the soil through its soil-atmosphere interface (Mirsha 2004). Infiltration and hydraulic characteristic of soils have been shown to vary widely spatially and temporally. (Folorunso and Olorunjo 1986). This variability emanates from heterogeneities in the physical properties (Mirsha 2004). Infiltration is

Table 2. Some physicochemical Properties of the Study Area.

Site	Depth (cm)	B.D (g cm^{-3})	P.D (g cm^{-3})	Porosity (%)	W.H.C (%)	pH 1:2	EC (dSm^{-1})
1A.	0-20	1.57	2.51	22.71	25.10	6.5	1.5
	20-50	2.00	2.63	61.97	20.01	6.6	1.4
1B.	0-20	1.54	2.41	37.45	21.10	7.4	1.1
	20-50	1.86	2.55	33.72	23.30	7.6	1.0
2A.	0-20	1.50	2.40	20.83	21.12	7.1	1.0
	20-50	1.80	2.61	30.65	24.40	6.7	1.3
2B.	0-20	1.30	2.45	20.83	21.12	7.1	1.1
	20-50	1.20	2.11	11.26	21.61	6.9	1.5
3A.	0-20	1.62	2.43	25.51	24.23	6.3	1.1
	20-50	180	2.71	29.52	22.20	6.5	1.5
3B.	0-20	1.82	2.7	31.99	22.7	6.8	1.2
	20-50	1.54	2.5	22.73	25.1	6.5	1.5
4A.	0-20	1.86	2.15	40.00	20.10	6.8	1.1
	20-50	1.96	2.60	36.92	23.01	6.9	1.5
4B.	0-20	1.24	2.13	11.26	21.61	7.0	1.5
	20-50	1.50	2.56	19.53	24.45	6.4	1.1
5A.	0-20	1.50	2.18	22.94	23.60	6.9	1.2
	20-50	1.68	2.76	24.63	25.00	6.1	1.3
5B.	0-20	1.54	2.11	25.59	21.10	7.0	1.0
	20-50	1.84	2.71	30.99	22.50	6.8	1.1

governed by two forces, gravity and capillary action. While smaller pores offer greater resistance to gravity, very small pores pull water through capillary action, in addition to an even against the force of gravity (Mirsha 2004). The rate of infiltration is affected by soil characteristics including ease of entry, storage capacity and transmission rate through the soil. The soil texture, structure, vegetation types and cover, water content of the soil, soil temperature and rainfall intensity all play role in controlling infiltration rate and capacity (Ghildyal et al. 2003). Coarse grained sandy soils have large spaces between each grain and allow water to infiltrate quickly. Vegetation creates more porous soils by both protecting the soil from pounding rainfall, which can close natural gaps between soil particles and losing soil through root action. Infiltration rate therefore plays a key role in water movement processes in the soil and have direct implication with management and crop production (Mirsha 2004). It also determines the amount of runoff. Loko area has been a center of agricultural activity both during the rainy and dry season for many years. The area has equally recorded high yields of both cereals and horticultural crops over the years. These in recent years have encouraged the influx of people migrating from other parts of the country to the area with consequent effect of increased population density, thus exerting pressure on available soil resources (Komolafe 2015).Flooding is a seasonal ecological problem in Loko and its environment. Addressing water use efficiency and movement on and within soil will not only reduce the mean of soil degradation particularly through water erosion as a result of flooding, but will improved soil fertility, food production and general food security and reduce poverty.

MATERIALS AND METHODS

The project site known as lower Loko lies west of song town of Song Local Government, Adamawa state. It is located within longitude 12,350 N and latitude 09,460E. The tributary river originating from Benue river. There (30) hectares of land partitioned into small farm owned by different farmers, Cultivated continuously both in rainy and dry season. The site was randomly selected during the preliminary survey of the study area, and infiltration was carried out and samples were collected for laboratory analysis; texture, bulk density, particle density, soil pH, organic carbon, soil water holding capacity and porosity were determined. Infiltration study was carried out, using a double ring infiltrometer method (FAO 1979). The test was carried out on the ten (10) randomly selected area and measurements were taken at intervals of 2 minutes for the first 10 minute then at 5, 10, 20, 30 and 60 minutes for the period of three hours.

Soil samples were collected from 0-20cm depth and 20-50cm depth from both sites using a tabular auger at the time of infiltration. Samples were labeled and preserved in polythene bags. The samples so preserved were air dried, ground using a porcelain pestle and mortar and passed through 2mm sieve. These were used for all routine physical and chemical laboratory analyses using standard laboratory procedures, coefficient of variability (C.V) were also determined using Microsoft Excel (2010) for the infiltration.

RESULTS AND DISCUSSION

The results of particle size analysis showed that both surface soil depths (0-20) and sub-surface (20-50) were dominantly sandy loam (SL). While site 3B at 20-50, 4A and B, 5A at 20-50 and 5B at 20-50 was dominantly sandy clay loam (Table 1). Soil physical properties of a soil determine its suitability for crop production (Brady and Weil 2008; Odeh 2008). Moisture storage and availability to plant, drainage, ease of root penetration, aeration, and retention of plant nutrient have been reported to be intimately linked to soil physical properties (Brady and Weil 2008). Water holding capacity, Bulk density, particle density and soil porosity are all linked to soil- plant- water relations (Brady and Weil 2008). Particle density of the soil ranged from 2.11 to 2.76g cm^{-3} at both surface and subsurface soil with a means of 2.46 g cm^{-3}. The averagely 2.5 gcm^{-3} particle density indicated that the soils are dominantly of feldspars

Table 3. Mean infiltration Characteristics of the Study Area.

Site 1	Initial IR ($cmhr^{-1}$)	Final IR ($cmhr^{-1}$)	CI ($cmhr^{-1}$)
A	4.77	5.46	2.21
B	5.34	6.34	1.00
Mean ± SD	5.10 ± 3.89	5.9 ± 4.04	1.61± 0.93
CV %	76.23	68.47	57.76
Site 2			
A	4.65	8.26	2.10
B	4.99	8.47	3.36
Mean ± SD	4.82 ± 4.06	8.37 ±5.33	2.73 ±1.37
CV %	84.23	63.68	50.18
Site 3			
A	3.78	4.98	1.61
B	5.82	7.92	2.69
Mean ± SD	4.80 ± 3.23	6.45 ± 3.97	2.15 ± 0.92
CV %	67.29	61.55	42.79
Site 4			
A	5.46	7.73	2.75
B	5.62	11.61	5.49
Mean ±SD	5.53 ±4.53	9.67 ±4.61	4.12 ±1.95
CV %	89.92	47.67	47.33
Site 5			
A	5.86	8.65	2.66
B	4.75	10.26	6.58
Mean ± SD	5.31 ±4.49	9.46 ±1.96	4.62 ± 4.16
CV %	84.64	20.73	90.04

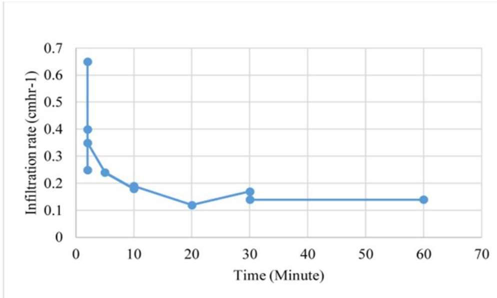

Figure 1. Site 1A infiltration rate graph

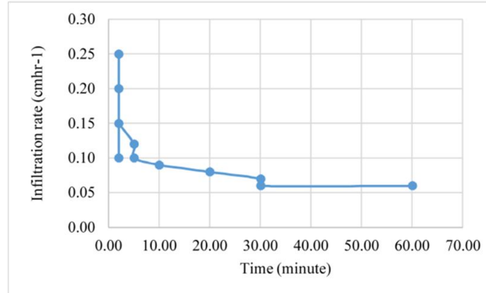

Figure 2. Site 1B infiltration rate graph

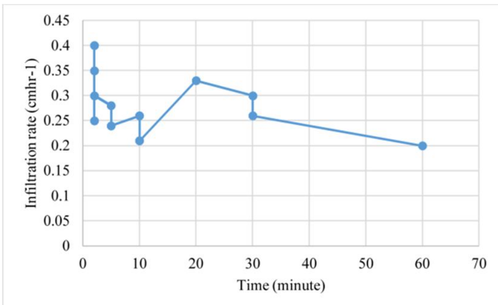

Figure 3. Site 2A infiltration rate graph

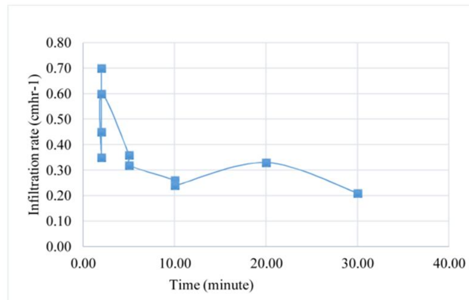

Figure 4. Site 2B infiltration rate graph

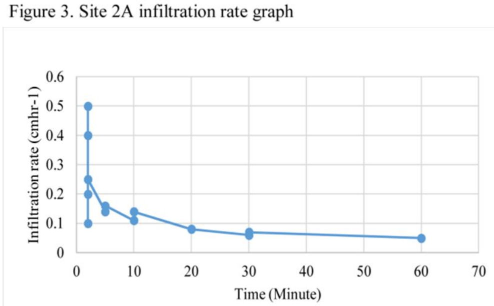

Figure 5. Site 3A infiltration rate graph

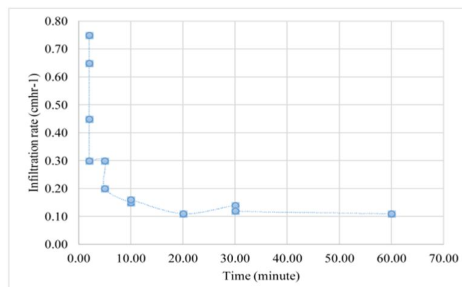

Figure 6. Site 3B infiltration rate graph

mineral. The Bulk density of the soil ranged from 1.24 to 2.0 gcm^{-3} with a means of 1.66 gcm^{-3}. Higher bulk densities were however observed at the subsurface soils and may be attributed to impact of thousands of grazing animals in the area. Water holding capacity of the soils ranged between 21.12% soils to 25.10% soil from 0-20cm soil depth. The total water holding capacity of site 1A and B, 2A and B, 3A and B, 4A and B, 5A and B across the depth, of 0-20 and 20-50cm was found to be 449.65%, soil (Table 2). This when compared with cumulative infiltration of 9.68cm for the soil, water must have infiltrated into the soil and percolated down to lower horizons. Although the water intakes of all the sites were low, it indicated infiltration and percolation beyond the 50cm soil depth (Table 3). Soil pH ranged from 6.1 to 7.6 in both surface and sub-surface soils with comparatively lower pH values at the surface (Table 2). The comparatively higher pH values recorded at the sub-surface may be attributed to eluviation and illuviation of salts as consequence of continues irrigation. The organic carbon content ranged from 1 to 1.5% in both surface and sub-surface. Contrary to pH, the organic carbon content was comparatively higher at surface compered to sub-surface. This may attributed to accumulation of O.M at the surface (Table2).

Infiltration studies

The data from the double ring infiltration tests (Figure 1-10) were compared by the linear plots of each site of infiltration test (site 1 to 5) and statistical analysis (Table 3). There exists little variation in the infiltration characteristics of the area as shown in figure 1-10. The initial infiltration rate was low for the entire site of 1A and B, site 2A and B, site 3A and B, site 4A and B and site 5A and B, with a ranged of 3.78cmhr^{-1} to 5.82 cmhr^{-1}. The low infiltration rate variation may be due to the variation in the porosity of the area as consequences of bulk density variation in addition of ant hills were also common in the fields. Bulk density is inversely related to porosity. (Brady and Weil, 2008). Adeoye et al. (2008) reported that pore size distribution that skewed toward smaller

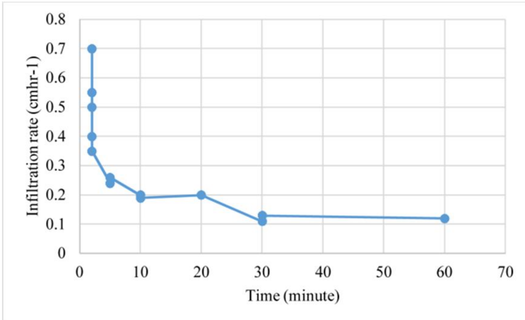

Figure 7. Site 4A infiltration rate graph

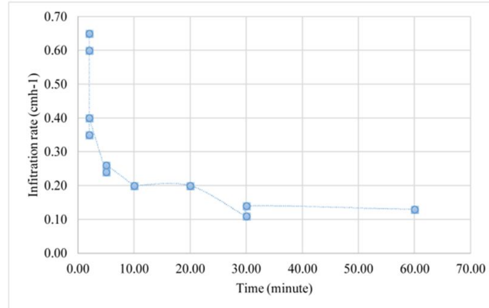

Figure 8. Site 4B infiltration rate graph

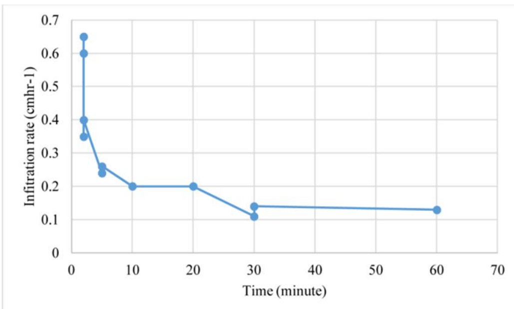

Figure 9. Site 5A infiltration rate graph

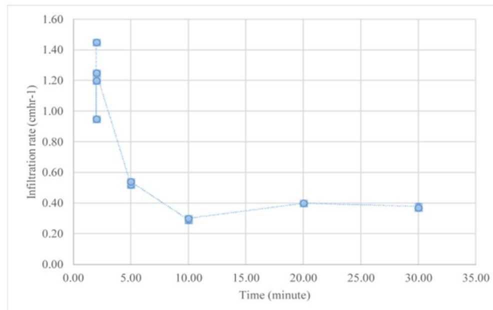

Figure 10. Site 5B infiltration rate graph

pore results in decreased infiltration while those skewed towards large pore enable water to penetrate, hence the lower water intake in all the sites may be due to the high bulk densities of the subsoil (Table 2.) Brady and Weil (2008) reported that ants hills contributes to increased soil porosity and fast water percolation due micro pores abundance in the soil. Folorunso et al. (1986) reported averaged water infiltration rate of 13.49 cmhr^{-1} for soil of Borno states with coefficient of variability of 24.83%. The cumulative infiltration was low in the entire site and ranged from 1.00cm to 6.58cm. Site 5A has the highest initial infiltration average of 5.86 cmhr^{-1}. However, great variation exists within the sites, as site 4B has initial infiltration of 1.50 cmhr^{-1} and site 5B has 1.45 cmhr^{-1} (Table 3). The high water intake in site 4B and 5B was due to the abundance of ants' holes which makes the soil extremely porous. Steady basic infiltration rate (BIR) of 0.90 cmhr^{-1} reached at 10, 30, and 60 minutes lasted for all 30 minutes for site 1B, indicating very rapid infiltration rate. Lando (1991) reported infiltration rate of below 12.5 cmhr^{-1} to be low and 0.21 cmhr^{-1} steady basic infiltrations was attained after 20 minute which last for 60 minutes in site 2B, 0.30 cmhr^{-1} steady basic infiltration rate was attained after 5 minute which last for 30 minute in site 3B. Also 0.39 cmhr^{-1} steady basic infiltration rate was attained at about 30 minute which last for 60 minute in site 4B. Similarly 0.38 cmhr^{-1} steady basic infiltration was attained after 20 minute and last for 60 minutes in site 5B. Coefficient of variability (cv) of all the site is very high (Table 3). This result is in conformity with Gubiani et al. (2011).

CONCLUSION

In all the sites, site 1 recorded average infiltration rate of 1.61 cmhr^{-1} with coefficient of variability of 57.76 % (Table 3). Similarly, 2.73, 2.15, 4.12, 4.62 cmhr^{-1} and coefficient of variability of 50.18, 42.76, 47.33 and 90.04% respectively were recorded at site 2, 3, 4 and 5.The results therefore suggest high water infiltration variability across the five sites. However sites 1, 2 and 3 had low average water infiltration rates and therefore more susceptible to water runoff and flooding compared to site 4 and 5 with higher average infiltration rates.

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