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WATER INTAKE CHARACTERISTICS OF DIFFERENT SOIL TYPES IN SOUTHERN BORNO NIGERIA

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ABSTRACT

The water intake characteristics of soils under arable crop practice were studied with a view to obtaining useful information for the design of irrigation and drainage system and for effective soil management techniques. Parameters determined; infiltration, hydraulic conductivity, permeability, bulk density, particle density, porosity and moisture content. The textural class of the soils from the three sites was found to be clay. The result obtained indicates that infiltration was high initially but decreases later. This may be due to the soil reaching a saturation point. On the average the infiltration rate was observed to decrease with time. The coefficient of permeability was found to be 9.26 x 10 , 7.66 x 10 and 2.15 x 10 cm/s for site A, B and C respectively. Information on infiltration and permeability are useful tools in irrigation and other engineering design.

Keywords:water intake rates, Bio soils, semi-arid region, Nigeria.

INTRODUCTION

Soil water is one of the principal factors limiting the growth of plants especially in arid and semi-arid environment where annual precipitation is low. Optimum plant growth depends also as much on a favorable soil physical environment as it does on what we call soil fertility. One of the major problems encountered by soil users is the inadequate practical-analytical knowledge of the rate at which water moves downward into the soil often referred to as the infiltration. The rate of infiltration determines the amount of water, which will enter the soil and the amount of water, which will run on soil surface as runoff after any precipitation [1]. Therefore infiltration rate can be viewed as an important soil property that significantly influences the potential and severity amount of surface runoff and hence, the degree of soil erosion. Since most areas of land are used for agricultural production, a small loss in the infiltration capacity of agricultural soils may produce serious impacts on flood intensity. For instance, water infiltration rates less than 15 mm/h were found to be related to increased flood intensity [2]. Therefore, sustaining enhanced water infiltration ability into the soil of agricultural areas is considered as a precautionary way for protection against river floods. It is therefore an essential tool in soil conservation and management [2]. De Lima et. al.[3] reported the spatial variability of soil hydraulic properties as the basis of the observed differences in runoff response.

It is quite obvious that water is one of the principal factors limiting the growth of plants especially in arid and semi-arid environment. The response of soils to availability of water or otherwise such as erosion, crusting, sealing, etc often depress the quality and productivity of the soils. This adversely affects agricultural production in many places. The knowledge of the water intake characteristics of a given soil, therefore, has a significant role in the selection of type crops, irrigation, drainage, and soil and water management technique. Clay soil for instance has very low and correspondingly, has high tendency to pond water. Adequate practical-analytical knowledge of the rate at which water moves downward into the soil is hence of great importance to soil users, either in for crop production or in soil related engineering. Water intake characteristics data are scanty in the study area. This study was therefore initiated to improve on the understanding of the intake characteristics of soils in Biu area, Borno, Nigeria. Specific objectives include the determination of infiltration rate, hydraulic conductivity, soil moisture content, bulk density of the soil, particle size distribution of the soil using sieve and hydrometer method, particle density and porosity.

MATERIALS AND METHODS

Study Area:

The study was conducted in three different farms of about one hectare each cultivated with maize/cowpea, guinea corn/coco-yarn, and guinea corn/cowpea which are located at Nasarawa Area, College of Education Waka-Biu and along BiuNuman by-pass at Biu, Biu local Government area of Borno state, in the north-eastern part of Nigeria. Three seasons have been identified, the colds dry (harmattan) season (October - March), hot dry season (April- June) and rainy season (July-September) in the study area. Biu is a plateau that is underlain by a basement complex. The Biu plateau is a structural and topographical divide between the upper Benue basin to the south and the Chad basin to the north. The area has fertile soils in the valley bottoms, but the skeletal soils and rock outcrops occurs along the gentle and steep slopes. The weather in Biu plateau is relatively mild. The rainy season lasts for l40 days with a mean annual rainfall of 600-800 mm, but less than 500 mm at the extreme north around Lake Chad.

Three locations, roughly spaced 4-5 Km apart were selected for the study. These are Nasarawa area (NA), College of Education Waka-Biu (COEB) and BiuNuman by-pass (BNBP) each was under different cropping land management practices with maize/cowpea, guinea corn/coco-yam, cowpea/guinea corn respectively. The study were carried out towards the end of the 2010 rainy season.

Field experiments:

Infiltration rates were determined at five (5) spots in an 'X' pattern in each of the each study sites using the double ring infiltrometer method adopted from Diamond, J. and Shanley [4]. The diameters of the inner and the outer rings of the infiltrometer were 30 mm 60 mm. Soil samples at 15 cm incremental depth from top soil to 60 cm depth were collected and conveyed to laboratory for gravimetric moisture content (GMC) determination. Soil samples were oven-dried at 105^{o}C for 24 hrs percentage moisture losses were computed. The permeability was determined using a falling head permeameter method [5]. The hydrometer method was adopted for the particle size analysis. A pyconorneter was used for the determination of the particle density [5]. Three standard core samplers were used to collect soils in each of the collection spots for bulk density determination. The total porosity (Pt) was computed using the values of the of particle density (Pd) and bulk density (BD) using the expression in Eq. 1 [5].

$$Pt = 100 (1 - BD / Pd) \quad (1)$$

RESULTS AND DISCUSSION

Infiltration Rates:

Tables 1, 2 and 3 show the infiltration data obtained from the field tests for NA, COEB and BNBP respectively. It was observed that in all the locations, the first four (4) minutes have relatively high values of infiltration rates.

Time Elapse (min)	Average water Level (cm)		Average Depth h (cm)	Average Infiltration rate	Average cumulative infiltration
	1st	2nd			
4	10	9.17	0.83	12.50	0.90
16	10	8.90	1.10	8.25	2.00
28	10	8.23	1.77	8.83	3.60
44	10	7.70	2.30	8.63	5.80
64	10	7.00	3.00	9.00	8.60
88	10	6.63	3.37	4.59	11.90
116	10	6.23	3.77	4.18	15.70
146	10	6.07	3.93	3.72	19.70
178	10	6.03	3.71	3.21	23.70
212	10	6.00	4.00	2.86	27.70

Table 1: Average Infiltration Data at site NA

Time Elapse (min)	Average water Level (cm)		Average Depth h (cm)	Average Infiltration rate	Average cumulative infiltration
	1st	2nd			
4	10	8.13	1.87	28.00	1.89
16	10	7.53	2.47	18.50	4.33
28	10	7.07	2.93	14.67	7.27
44	10	6.53	3.47	13.00	10.73
64	10	5.33	4.67	14.00	15.40
88	10	4.60	5.40	13.50	20.80
116	10	3.67	6.33	13.57	27.13
146	10	3.33	6.67	13.33	33.80
178	10	3.25	6.75	12.66	40.14
212	10	3.22	6.78	11.94	46.27

Table 2: Average Infiltration Data at site COEB

Time Elapse (min)	Average water Level (cm)		Average Depth h (cm)	Average Infiltration rate	Average cumulative infiltration
	1st	2nd			
4	10	8.15	1.84	27.75	1.85
16	10	7.00	3.00	18.50	4.85
28	10	6.77	3.23	16.17	8.08
44	10	6.20	3.80	14.25	11.88
64	10	5.37	4.63	13.90	16.52
88	10	4.90	5.10	12.75	21.62
116	10	4.00	6.00	12.86	27.62
146	10	3.60	6.40	12.80	34.02
178	10	3.30	6.70	12.56	40.72
212	10	3.35	6.65	11.74	47.42

Table 3: Average Infiltration Data at site BNBP

The high value obtained in the first few minutes could be attributed to high organic matter content found in the soil, and likely, coarse soil particles at the top soil level. This implies that the soil was not highly saturated therefore, more water infiltrated into the soil much more rapidly at the initial stage of the experiments than after 28 minutes.

A constant value was attained from the 178th minutes (Table I, 2 and 3). This behavior may suggest either the presence of a hard pan or saturation of the profile deeper down as more water is applied. As the soil approaches saturation point, less water infiltrates in to the soil because all soil pores are almost filled with water. Hence, allowing only little infiltration rate. Clogging of the soil pores due to alleviation of clay particles from the surface soil to the sub-surface soil might also be responsible for the lowering in the infiltration rate.

Particle Density, Porosity, and Bulk Density:

The result obtained from bulk density, particle density determinations, and computations of total porosity for the various depths are shown in (Table 4). Depth 0-0.5m has bulk density of 1 .637g/cm^3 , depth

0.5-1 .0m has bulk density of 1 .739g/cm^3,and depth 1.0-1 .5m has bulk density of 2.057g/cm^3 which are the average bulk density of the three sites. This shows an increase in value of bulk density with depth which an index of the degree of compaction due to the weight or underlying horizons.

Compaction destroys the layer pores partially filling them with solid particles, thus resisting the flow of water. This may be true for the site because farming activities have been going on in the area for quite some time. It was also observed that the porosity of the soil decreased with depth at each site (Table 4). Some thick layers of alluvial deposits were encountered at the time of profile digging and were very much compacted physically showing high clay deposition. The unstable values of the porosity are influence by particle density values used in the computation of porosity and this therefore may be attributed to inconsistency in profile characteristics. History revealed that the field has been under consecutive cultivation over the years and so this might have caused some degree of compaction. Besides, the effect of the animals grazing on the area might be significant. Judging from the value of total porosity, this soil can be described as having low aeration and reduced drainage.

	Site NA			**Site COEB**			**Site BNBP**		
	0.5m	**1.0m**	**1.5m**	**0.5m**	**1.0m**	**1.5m**	**0.5m**	**1.0m**	**1.5m**
Particle Density	2.5233	2.3742	2.553	2.5341	2.4882	2.5272	2.551	2.3256	2.5628
Bulk Density	1.714	1.754	2.106	1.535	1.754	2.204	1.622	1.71	1.861
Total Porosity	0.321	0.261	0.175	0.394	0.295	0.128	0.364	0.265	0.274

Table 4: Particle Density, Bulk Density, and Porosity for various depths

Permeability:

The total average coefficient of permeability obtained from this experiment was found to be 9.26 x l0^{-6}cm/s, 7.66 x 10^{-6} cm/s and 2.15 x 10^{-4}cm/s at NA, COEB and BNBP sites respectively (Table 5). The results fall within the values suggested by Craig 1974 concerning clay soils. His suggestion followed that clay soils should have the coefficient of permeability ranging from 10 to l07mm/sec.

SITES	AVERAGE PERMEABILITY (cm/sec)
NA	9.26×10^{-6}
COEB	7.66×10^{-6}
BNBP	5×10^{-4}

Table 5: Average coefficient of permeability for the study area

CONCLUSION

The study of water intake characteristic of Biu soils, Borno state, shows that the infiltration rate of the soil was high during the first few minutes of the practical but decreases with time. The average coefficient of permeability 'K' of the soils were found to be 9.26 x l06cm/sec, 7.66 x l0cm/sec, and 2.15 x l0^{4}cm/sec at sites NA, COEB, and BNBP respectively. The bulk density and porosity of the soil were also found and the result shows that the bulk density of the soil increases with depth while the porosity decreases with depth. This could be due to compaction of the soil as a result of agricultural activities going on in those areas over the years.The areas studied have good potentials for increase food production in terms of the available arable land. Therefore, there is need for dry season farming through irrigation using modem techniques.

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