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RESPONSE OF SOIL MOISTURE CONTENT TO SAMPLING DEPTH AND CANOPY TYPES IN A TROPICAL CLIMATE, SOUTHWEST NIGERIA

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ABSTRACT
Soil moisture plays a very important role on vegetation growth and hydrological cycle in tropical wet and dry climates. Response of soil moisture to sampling depth and canopy type in a tropical wet and dry climate, South-West Nigeria was assessed during 2015 meteorological year. The selected canopy types were Cashew plantation(*AnacardiumOccidentale*) (7°.43[1]N, 3°.85[1]E), Teak plantation (*Tectonagrandis*) (7°.66[1]N, 3°.84[1]E) and Palm tree plantation (*Elaeis guineensis*) (7°.51[1]N,3°.99[1]E) all in the Federal University of Agriculture, Abeokuta, Nigeria. Result showed that the moisture values under the Palm tree canopy obtained from the three methods was significantly ($p \leq 0.05$) higher than moisture content from other canopy types, though soil moisture under Cashew had slightly higher moisture readings than those under Palm canopy sometimes. In terms of sampling depth, soil moisture determined by gravimetric method at 10cm depth ranged from 2.92 to 9.48, then at 20cm ranged from 3.41 to 9.46 while at 30cm, it ranged from 3.77 to 9.57. Soil moisture readings obtained using volumetric method at 10cm ranged from 3.62 to 10.30, then at 20cm ranged from 3.79 to 9.87 while it ranged from 4.42 to 11.73 at 30cm depth. The values of soil moisture using TDR method at 10cm depth ranged from 3.31 to 8.46, then at 20cm, it ranged from 3.14 to 9.03 while at 30cm ranged from 3.43 to 9.79. Conclusively, leaves attached to palm tree perhaps maintained their saturated water content longer than leaves attached to shorter trunk such as cashew and teak trees, hence less moisture uptake by palm tree in contrast to cashew and teak trees.

Keywords: Soil moisture, Teak plantation, Cashew Plantation, and Palm Plantation

Introduction

Much of Nigeria is semi-arid, where vegetation structure and biomass production are controlled by soil water availability which is mainly a function of the precipitation regime and soil properties. Moisture content is the quantity of water contained in a material, such as soil, (called soil moisture), rock, ceramics, fruit, or wood. Water content is used in a wide range of scientific and technical areas and is expressed as a ratio, which can range from zero (completely dry) to the value of the materials porosity at saturation. It can be given on volumetric or mass (gravimetric) basis. The important role of soil moisture for the environment and climate system is well known. Soil moisture influences hydrological and agricultural processes, runoff generation, drought development and many other processes. It also impacts on the climate system through atmospheric feedbacks. Soil moisture is a source of water for evapotranspiration over the continent and is involved in both the water and energy cycles. Soil moisture was recognized as essential climate variable. In arid and semi-arid regions, water represents the main ecological constraint for plant survival and hydrological processes determine the direction of evolution and ecological functioning of soil-vegetation systems (Li, 2011). Therefore, understanding the relationship and coupling mechanisms among soil, water and vegetation interactions can help to understand the land surface development processes and biogeochemical balances. Soil moisture dynamics are the central component of the hydrological cycle (Legates *et al*., 2011) and are mainly determined by processes including infiltration, percolation, evaporation and root water uptake. Soil moisture plays a significant role in land-atmosphere interactions. The state of soil moisture as described by the level of saturation in the upper layer relative to the soil field capacity is regulated by rainfall and potential evaporation. Both of these atmospheric forcing exerts significant control on the evolution of the soil moisture state and appear explicitly in the soil water balance equation. On the other hand, the level of saturation determines the availability of water as well as the hydraulic properties of the soil and for this reason; soil saturation exerts significant control on the rates of infiltration and subsequent evaporation (Chen *et al*., 2008a). However, the role of soil moisture conditions in dictating the occurrence of future rainfall is less understood. Clarification of this role requires identification of the pathways through which soil moisture may regulate the atmospheric variables that are relevant to the dynamics of storms and rainfall. In future, rainfall levels over any region reflect in some way the current state of soil moisture, then that condition implies the existence of a feedback mechanism between the two variables. In this paper, we propose a pathway for relating soil moisture conditions and subsequent rainfall. Soil moisture is the environmental variable synthesizing the effect of climate, soil and vegetation on dynamics of water-limited ecosystems. Unlike abiotic factors (e.g., soil texture and rainfall regime), the control exerted by vegetation composition and structure on soil moisture variability remains poorly understood. Thus, because water is the limiting factor for vegetation in tropical wet and dry climate ecosystems, a positive feedback can exist between soil moisture and vegetation cover (Fu *et al.* 2011). Thus, understanding the interactions between vegetation types and soil moisture is urgently required as basis for adjusting land use structures and ensuring sustainable provisions of desired ecosystem services Many investigators have paid a great deal of attention to soil desiccation resulting from the excessive depletion of deep soil water by artificial vegetation and long-term insufficient rainwater supplies (Li, *1983;* Li and Shoal, 2001*;* Chen *et al.*,2007a). The present study was to investigate the response of soil moisture content to sampling depth and canopy types in a tropical climate, South-west Nigeria.

Materials and Methods

Study Area

The study was conducted under three selected canopies in Federal University of Agriculture, Abeokuta (FUNAAB) Nigeria. The selected canopies are Cashew plantation(*AnacardiumOccidentale*) at College of Animal Science (COLANIM) farm, on 7°.43¹N, 3°.85¹E, Teak plantation (*Tectonagrandis*) at Agro-Forestry Nursery opposite ceremonial ground on 7º.66¹N, 3º.84¹E and Palm tree canopy beside Guarantee Trust Bank along FUNAAB gate on 7º.51¹N,3º.99¹E. The soil at the experimental site was classified as a well-drained tropical ferruginous soil, with a sand-loamy surface horizon, underlain by a weakly developed clayed mottled and occasionally concretionary sub-soil. It has 83.3% sand, 4.6% silt and 12.1% clay, within a pH of 6.2. The study fall within the part that is underlain by parent rock belonging to the mignatite-gnesis complex, consisting of biotite hornblende gnesis, quartzite and quartz schist with small lenses of cale-silicate rocks (Rahman 1976). The site is undulating with extensive mild slopes. It is punctuated in parts by ridges, isolated residual hills, and plateau, valley, landscape with lowlands. Both the topography, especially mountain ridges coupled with dense vegetation constitute one of the greatest assets for site.

Sample collection

Samples were taken in randomized complete block design from each canopy type at the depth of 10cm , 20cm, 30cm replicated thrice. This resulted to nine samples under each canopy and the samples were taken twice a month for four and half months, March – July 2015, (nine weeks).

Sample preparation and analysis

Afterwards the collected samples were taken to the laboratory for determination of moisture content gravimetrically which involves weighing the wet soil sample, removing the water content of the soil by oven drying at 105°C, and reweighed to determine the amount of water removed and Volumetrically using the bulk density method as shown below. Moisture content in-situ had earlier been determined by time-domain reflectometry.

The gravimetric soil moisture content, θg, defined by $\theta g = {}^{\mathrm{Mwater}}/_{\mathrm{Msoil}}$

where M_{water} is the mass of the water in the soil sample and M_{soil} is the mass of dry soil that is contained in the sample. Values of θg in meteorology are usually expressed in per cent

The volumetric soil moisture content of a soil sample, θ_v , is defined as: $\theta v = \frac{\mathrm{Vwater}}{\mathrm{Vsample}}$

where V_{water} is the volume of water in the soil sample and V_{sample} is the total volume of dry soil + air + water in the sample

Statistical data analysis

Data collected were subjected to analysis of variance (ANOVA) to evaluate the effects of sampling depths and canopy types on the soil moisture content response variables. The significant difference of treatment means were determined using least significance difference (LSD) at 5% level of probability (Steel and Torrie, 1997).

Results and Discussion

Table 1 shows impact of canopy type on the soil moisture content using gravimetric method. Soil moisture content under cashew plantation (7.79) was highest followed by palm plantation (4.85) while least soil moisture content was observed under teak plantation in the first week of sampling (March). However, in second week of sampling, soil moisture content (6.97) under palm tree plantation was highest followed by that under cashew plantation with 5.40g/100g while the least was also from teak plantation. Generally, soil moisture content under palm plantation was significantly higher than moisture content under cashew and teak plantation; this could be probably due to the vigorous nature of the palm tree which reduces the amount of evaporation by preventing the absorbed water from escaping into the atmosphere.

Table 2 shows the impact of canopy type on the soil moisture content using volumetric method. Soil moisture content under cashew plantation (13.85) was highest followed by soil moisture under palm plantation (7.02) while the least (2.91) soil moisture content was observed under teak plantation in first week of sampling in March. However, in second week sample, soil moisture content (8.04) under palm tree plantation was highest followed by that under cashew plantation with 7.95g/cm3 while the least of 3.49 was observed under teak plantation. Generally, for the period under observation soil moisture content under palm plantation was significantly higher than moisture content under cashew and teak plantation, this could be probably due to the vigorous nature of the palm tree which reduces the amount of evaporation by preventing the absorbed water from escaping into the atmosphere.

Table 3 presents the impact of canopy type on the soil moisture content using Time-Domian reflectometer (TDR) method. Soil moisture content under cashew plantation (11.59 g/cm^3) was highest followed by soil moisture under palm plantation (6.21 g/cm^3) while the least (2.33 g/cm^3) soil moisture content was observed under teak plantation in first week of sampling in March. However, in second week samples, soil moisture content of 8.42 g/cm^3 under palm tree plantation was highest followed by that under cashew plantation with 7.52 g/cm^3 while the least of 3.34 g/cm^3 was observed under teak plantation. Soil moisture content under cashew plantation ranged from 11.59 to 1.99. This was followed by soil moisture under palm plantation which ranged between 8.42 to 4.81 g/cm^3, while the soil moisture content under Teak plantation ranged between 8.92 to 2.33 g/cm^3.

Table 4 shows impact of sampling depth on the soil moisture content using gravimetric method. Soil moisture content at 30cm depth of 5.40 was highest followed by soil moisture at 20cm depth of 4.92 while least soil moisture content of 3.87 was observed at 10cm depth in first week of sampling in March. However in second week, soil moisture content of 5.57 was obtained at 30cm depth was highest followed by 4.87 at 10cm depth while the least moisture content of 4.33 was also obtained at 20cm. Soil moisture at 10cm depth ranged between 2.92 to 9.48 then at 20cm depth ranged between 3.41 to 9.46 while it ranged between 3.77 to 9.57 at 30cm depth for the period under consideration.

Table 5 revealed the impact of sampling depth on the soil moisture content using volumetric method. Soil moisture content at 30cm depth of 9.49 was highest followed by soil moisture at 20cm depth of 8.36 while least soil moisture content of 5.93 was observed at 10cm depth in first week of sampling in March. However in second week of sampling, soil moisture content of 7.03 was obtained at 30cm depth. This was highest followed by 6.79 at 10cm depth while the least moisture content of 5.66 was also obtained at 20cm. Soil moisture at 10cm depth ranged between 3.62 to 10.30 then at 20cm depth ranged between 3.79 to 8.36 while it ranged between 4.42 to 11.73 at 30cm depth for the period under consideration.

The impact of sampling depth on the soil moisture content using TDR is presented in Table 6. Soil moisture content at 30cm depth of 8.28 was highest followed by soil moisture at 20cm depth of 6.86 while least soil moisture content of 4.9 was observed at 10cm depth in first week of sampling in March. However in second week, soil moisture content of 6.59 was obtained at 20cm depth was highest followed by 6.54 at 30cm depth while the least moisture content of 6.16 was also obtained at 10cm. Soil moisture at 10cm depth ranged between 4.9 to 8.46 then at 20cm depth ranged between 3.79 to 9.03 while it ranged between 3.43 to 9.79 at 30cm depth for the period under consideration.

Table 7 presents the impact of canopy type on the soil bulk density from March to September 2015 in cashew, Teak forest and palm tree plantations. The table showed that bulk density of soil under different plantations was statistically difference at all sampled occasions. Bulk density of soil under cashew canopy ranged from 1.34 to 1.77g/cm^3, Teak forest ranged from 1.05 to 1.91 and Palm tree canopy ranged from 0.98 to 1.48g/cm^3.

Table 8 presents the impact of sampling depth on the soil bulk density from March to July 2015 at 10,20 and 30cm depth. The table showed that bulk density of soils at different depth was statistically difference at all sampled occasions. Bulk density of soil at 10cm depth ranged from 1.09 to 1.80g/cm^3, 20cm depth ranged from 1.04 to 1.67 and bulk density at 30cm depth ranged from 1.20 to 1.69g/cm^3.

Conclusion

Leaves attached to palm tree perhaps maintained their saturated water content longer than leaves attached to shorter trunk such as cashew and teak trees, hence less moisture uptake by palm tree in contrast to cashew and teak trees. The moisture content profile of palm, cashew and teak trees varied from depth to depth probably as a result of surrounding weeds inability to fully utilized the soil moisture in deeper part of the soil, thus the moisture content in 30cm and 20cm depth was higher than that at 10cm depth regardless of the canopy types and method of soil moisture estimation.

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Table 1: Impact of Canopy type on the Soil Moisture using Gravimetric Method (%)

	Sampling Dates								
	March		**April**		**May**		**June**		July
Location	05/03/15	19/03/15	18/04/15	25/04/15	09/05/15	15/05/15	23/06/15	29/06/15	05/07/15
Cashew	7.79	5.40	1.88	8.86	5.38	6.52	4.08	3.82	4.97
Teak	1.55	2.40	3.06	9.57	5.08	4.78	2.38	2.44	3.18
Palm tree	4.85	6.97	5.21	10.08	5.17	8.84	4.86	6.29	6.10
LSD (0.05)	0.71**	1.05**	0.75**	1.22	1.60	1.59**	1.09*	0.69**	1.45*

Table 2: Impact of canopy type on soil moisture content using volumetric method (g/cm^3)

	Sampling Date								
	March		**April**		**May**		**June**		**July**
Location	05/03/15	19/03/15	18/04/15	25/04/15	09/05/15	15/05/15	23/06/15	29/06/15	05/07/15
Cashew	13.85	7.95	3.04	11.92	7.05	8.89	5.42	5.39	6.65
Teak forest	2.91	3.49	3.46	10.02	5.53	6.43	3.08	3.42	4.17
Palm Tree	7.02	8.04	5.33	9.96	5.77	9.19	5.84	6.42	5.84
LSD (0.05)	1.13*	1.36*	0.87	1.39*	1.61	1.92*	1.39*	0.85**	1.49*

Table 3: Impact of canopy type on soil moisture using TDR(g/cm^3) method

	Sampling Date								
	March		April		May		June		July
Location	05/03/15	19/03/15	18/04/15	25/04/15	09/05/15	15/05/15	23/06/15	29/06/15	05/07/15
Cashew	11.59	7.52	1.99	9.60	5.28	7.27	4.07	4.46	5.71
Teak forest	2.33	3.34	3.09	8.92	4.87	6.21	2.94	2.47	3.32
Palm Tree	6.21	8.42	4.81	8.76	4.39	7.84	5.30	5.13	4.87
LSD (0.05)	0.44**	0.43*	0.41	0.93*	0.77*	1.35*	1.51	0.72	1.42

Table 4: Impact of sampling depth on Soil Moisture using Gravimetric method (%)

	Sampling Dates								
	March		April		May		June		July
Depth (cm)	05/03/15	19/03/15	18/04/15	25/04/15	09/05/15	15/05/15	23/06/15	29/06/15	05/07/15
10	3.87	4.87	2.92	9.48	7.02	7.45	3.78	3.96	4.23
20	4.92	4.33	3.41	9.46	4.60	7.27	3.72	3.61	4.67
30	5.40	5.57	3.81	9.57	4.01	5.42	3.77	4.98	5.35
LSD (0.05)	0.71*	1.05*	0.75*	1.22	1.60*	1.59*	1.07	0.69*	1.45

Table 5: Impact of depths on soil moisture using volumetric method (g/cm^3)

	Sampling Date								
	March		April		May		June		July
Depth (cm)	05/03/15	19/03/15	18/04/15	25/04/15	09/05/15	15/05/15	23/06/15	29/06/15	05/07/15
10	5.93	6.79	3.62	10.30	7.61	8.79	4.57	4.76	5.19
20	8.36	5.66	3.79	9.87	5.41	8.24	4.84	4.42	5.29
30	9.49	7.03	4.42	11.73	5.33	7.48	4.92	6.05	6.19
LSD (0.05)	1.13*	1.36*	0.87	1.39*	1.61*	1.92	1.39	0.85*	1.49

Table 6: Impact of depth on soil moisture using TDR

	Sampling Date								
	March		April		May		June		July
Depth (cm)	05/03/15	19/03/15	18/04/15	25/04/15	09/05/15	15/05/15	23/06/15	29/06/15	05/07/15
10	4.9	6.16	3.31	8.46	6.37	7.81	4.11	3.98	4.00
20	6.86	6.59	3.14	9.03	4.37	7.34	4.31	3.99	4.76
30	8.28	6.54	3.43	9.79	3.80	6.17	3.89	4.09	5.14
LSD (0.05)	0.44**	0.43**	0.41**	0.93	0.77*	1.35*	1.51*	0.72*	1.42*

Table 7: Impact of canopy type on the Soil bulk density (g/cm^3)

	Sampling Date								
	March		April		May		June		July
Location	05/03/15	19/03/15	18/04/15	25/04/15	09/05/15	15/05/15	23/06/15	29/06/15	05/07/15
Cashew	1.77	1.46	1.67	1.35	1.34	1.39	1.35	1.42	1.34
Teak forest	1.91	1.45	1.16	1.05	1.16	1.36	1.30	1.41	1.31
Palm Tree	1.48	1.15	1.05	0.99	1.12	1.05	1.21	1.02	0.98
LSD (0.05)	0.02**	0.03*	0.02**	0.02**	0.06*	0.04*	0.02**	0.02*	0.04*