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Spatial Variation of Throughfall in Two Tree Plantations in Abeokuta, South-Western Nigeria

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Abstract This paper determined the variability of throughfall in two tree plantations on the campus of University of Agriculture, Abeokuta, South Western Nigeria. It involved the use of experimental plots consisting of Tectona Grandis and Gmeliba Arborea. Gross precipitation and thoughfall were measured and determined for a month. The data obtained was analysed using simple descriptive statistics such as means, percentages and frequency counts. Correlation analysis was used to determine the relationship between gross precipitation and throughfall under each tree plantation. Results show that Tectona plantation had more throughfall throughout the period of study than that of Grnelna plantation. Also there is a strong relationship between gross precipitation and throughtfall in the two plantation. The implication of the results for the management and use of water resources in the study area were discussed and recommendations made as to how water trapped through interception can be better managed.

Keywords sInterception Loss, Throughfall, Tree Plantation, Gross Precipitation, Water Resources Management

1. Introduction

Over the years an increasingly popular aspect in the study of hydrology has been measurement of precipitation falling over the ground surface, beneath the soil and as discharge in flowing water bodies. Yet, an aspect that attracted much attention is that relating to the measurement of precipitation trapped or intercepted by vegetation cover and objects such as trees, special grasses and buildings. A probable reason for this may not be unconnected with the complex nature of evaluating the exact portion of precipitation that is actually trapped by the vegetation unlike that of open spaces where the estimation of gross precipitation is relatively free of interception and can therefore be directly done using conventional methods. The complex nature of assessing interception appears to be a fundamental factor prompting this study. The process of interception as described by Ayoade (1988) presents for some issues that demands close attention and by extension constitute areas for further research. The basic issue here relates to the task of estimating three quantities namely: *interception loss, throughfall and stemflow* Interception loss refers to that portion of precipitation remaining. Plant and leaf surfaces after most of the precipitation which a relater evaporated into the atmosphere or absorbed by these surfaces. Throughfall is that part of precipitation that touches the ground directly through spaces within the canopy of the vegetation and invariably from there, drips from leaves, and stems. Stemflow as the name implies is that portion of the precipitation which has been intercepted by the vegetation canopy and reaches the ground by running down the stems. Ayoade 1988, Jackson (1975), Voigt (1960) and Raich (1983). Of interest to this paper, however, is the issue of throughfall. It is one of the major sources of water loss through interception. Interception loss generally is often regarded as a form of major water loss like evapotranspiration in the sense that it does not add to the amount of water received on the ground surface that can directly be measured or assessed by any conventional method. However, it is an area of keen interest in surface hydrology in the sense that it constitute the net precipitation which is often part of the falling precipitation that actually reaches the ground eventually after the rainfall or when blown by the wind. This net precipitation later takes part in the land phase of the hydrological cycle and stands as an input into the hydrological system of a vegetated catchment area (Ayoade 1988 and Ward 1975).

In recent times, there has been arguments as to the significance of water loss through interruption particularly in the computation of the water balance of a catchment area, because of its complex nature and processes underlying it. This is so because the amount of precipitation intercepted usually depends on the nature and type of vegetation cover. Characteristics of vegetation under consideration here include that the vegetation type, density, form and age.

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Generally it is believed that the denser, the tree foliage, the greater the interception storage as the ability of the tree branches to trap precipitation is usually high. The influence of these factors has made the study of interception loss either through the process of through flow and stem flow to be interesting and attractive. This has over the years resulted in several studies carried out in determining the spatial variation in throughflow, stemflow and indeed overland flow over some vegetated surfaces. Studies such as that of Loescher, et al, (2002), Lloyd and Marques (1998), Pedersen (1992), Robson, et al (1994), Seiter and Matzner (1975), Sinun, et al, 1992) and Tobon, et al, (2000), Valente, et al (1997) and Whelan, et al, (1998) all fall into this category. These studies have confirmed the fact that intercepted water does not participate in near ground surface hydrological processes. In essence, there arises the urgency and the need to possess an in-depth knowledge of the magnitude of interrupted water involved which is fundamental to understanding the processes involved in interception situations and how to model such. This is necessary if it is appreciated that estimates of interruption in vegetated surfaces are usually influenced by the variability of throughfall. Hence, this study is executed for the purpose of determining the variation in throughfall in selected tropical forests in the southwestern part of Nigeria. This will provide more information that will serve as insights into the nature and processes of throughfalls in the selected forest vegetations and the factors that results in variations in the magnitude of throughfalls in the study area. This information will be extremely useful in the mapping and management of available water resources in vegetated surfaces in Nigeria (Amori 2009).

1.1. Research Problem

The study investigated and analyzed variation in throughfall and their relationship with gross precipitation in two tree plantations on the campus of the University of Agriculture, Abeokuta, and southwestern Nigeria.

1.2. Research Questions

The study provided answers to the following questions:

a. What is the amount of rainfall that got to the ground as gross rainfall and throughfall in the two tree plantations within the period of investigation?

b. What is the relationship between gorses precipitation and thrughfall in the two tree plantations?

2. Materials and Method

2.1. Study Area

The study area is located within the campus of the University of Agriculture, Abeokuta, Ogun State, Nigeria. The experimental site is beside the forest nursery of the University on Lat 7^o 2^{o}' N and Long 3^o 44' E) with an altitude of 138m above sea level. The site is characterized by a flat topography and about 1m lower to the main road level. The vegetation of the experimental site consists of two tree plantations (*Gmelina Arborea* and *Tectona Grandis*. The two plantations have trees planted 2.5m apart, which also consist of two sections having five year old and seven year old trees. The five year old trees are sited close to the main road while seven year old section are found at the back of the five year old trees. The five year old plantation were used for the experiment because of the freshness of the trees and its foliage. The two tree plantations have a combined area of 1000m^2, out of which 150m^2 was used for the experiment. Within this experimental site, there were 60 trees in all, that is, 30 trees for each plantation of the two plantations, the *tectonal grandis* tree plantation had more of a dense canopy cover that is branched to about 1.5m average from the ground. It has sparse undergrowth since the large canopy cover does not allow sunlight to penetrate that will encourage plant growth. Most *Teconal grandis* trees have a leaf area of 0.092m^2. *Gmelina arborea* tree plantation on the other hand has less dense canopies and it is branched to the average height of 10m from the ground surface. The canopy allows the penetration of sunlight thereby ensuring some measurable undergrowth. *Gmelna* trees have an average height of 14m and average leaf area of 0.037m^2. *Gmelina* by origin is a native of India and grows naturally in countries such as Myanmar, Thailand, Laos, Cambodia, Vietnam and southern provinces of China. In the last five decades it has been planted extensively in Sierra Leone, Nigeria and Malaysia. It attains a moderate height of up to 30m with a firth (width) of 1.2 to 1.45m with a clear bole of 9 to 15m and has a smooth whitish gray (ashy) curky bark. It is a light demander and tolerant of excessive drought.

Tectona grandis, otherwise known as Teak belongs to the family of tropical hardwood trees and a native of southern Asia. It is a component of monsoon forest vegetation. It is a large tree growing to a height of between 30 to 40m and is deciduous during the dry season.

2.2. Materials

The following materials were used in collecting the required data: PVC bottle gauges, steep slope PVC funnels, measuring tapes and measuring cylinders.

2.3. Data Collection

Data collection took place between 5th of September and 13th of October 2008 and was supervised by the researchers. The readings and measurements taken were on gross precipitation and through fall which were done on event basis. The readings were taken on 9.00 GMT after each event with the aid of a measuring cylinder.

2.4. Cross Precipitation

This was measured on the main lawn across the two tree plantations. Ten bottle gauges with PVC funnels mounted on them were used to collect the incident rainfall. The funnels had a V shape with steeps slopes which was to help prevent splashes of rainfall. Their diameter measures 10.7cm. The gauges were spaced in from each other and had a volume or capacity of 1 litre. The total height of each gauge is 25.4cm. The lawn on which the gauges were placed was characterized by vegetation made up of low grasses which helped in preventing any form of ‘splash in’ of raindrops form entering the gauges. Storms recorded in this study were averagely of low intensity and accompanied by light wind. The gauge were placed 5 metres from obstacles such as trees that are capable of encouraging error due to aerodynamics or wind turbulence which on the long run could result in alteration in the catch of the gauges. The values of gross precipitation were taken as the arithmetic mean of all the gauges for each precipitation events, which are ten in all.

2.5. Throughfall

Throughfall depths per each event were measured manually with fifty (50) bottles for each plantation making one hundred (100) in all. The gauges were mounted with PVC funnels having a 10.7m diameter resulting in a total captured area of 260m^2. The gauges were spaced 1cm form each other making five columns and ten rows for each plantation. Steep slope funnels were used so as to minimize the possibility of any splash out from the gauges during rainstorms. The gauges were of average height of 27cm form the ground. The maximum splash height of rain drops after hitting the forest floor was fund to be 25.5cm. This was shown by the height to which soil particles had been deposited on the sides of the bottles.

2.6. Data analysis

Data analysis involved the use of Statistical Package for the Social Sciences (SPSS) version 15.0 for windows while statistical techniques such as correlation, means, frequency counts, and percentages etc were sued in determining variability in throughfall and the relationship between gross precipitation and throughfall for each tree plantation. Descriptive statistics such as frequency account and percentages were specifically used in calculating and summarizing throughfall for each free plantation and the extent of variation of throughfall.

3. Results and Discussion

The result of the various measurements and readings taken during the study is presented in table 1. Ten storms were recorded during the period of study and readings were taken for each tree plantation.

Research question 1 was answered using descriptive statistics that is, frequency counts and percentages all of which are reflected in table 1. The second column shows the gross rainfall during the period of study for the ten storms. The highest value was recorded during the seventh (7th) storm to the tune of 26.28mm, followed by that of second storm with a value of 21.58mm. The remaining readings were below 10mm. This implies that for the ten storms, there was a drop in rainfall which may be attributed to the influence of the August break or the phenomenon of ‘little dry reason,’ experienced within the period. On the whole, the total gross rainfall recorded during the period of study was 75.43mm. Columns 3 and 4 show the average throughfall recorded for plantations A and B respectively during the ten storms. It appears that plantation A received more throughfall than Plantation B for the period of study. A probable reason for this may be due to the mophology of plantation A which allowed for more interception that that of plantation B. In spite of this, however, the differences are not appreciable or at best are minimal. Columns 5 and 6 show the percentages of each throughfall in relation to the gross rainfall. From the columns, none of the readings accounted for less than 50% of the grossfall. This implies that a sizeable amount of rainfall passed through the trees in each plantation to the ground without being trapped or intercepted by the branches and leaves of the trees. For the two columns, the percentage of throughfall to the gross rainfall ranged from 70.20% to 98.11%in column 5, and 58.00% to 88.60% in column 6 respectively. In all, the *Gmelina* plantation (plantation A had more throughfall compared to the *Tectona* plantation (Plantation B).

Table 1. Summary of Cross Precipitation and Throughfalls Recorded in the Two Tree Plantations

Storms/events	Gross rainfall (mm)	Average total throughfall (Plantation A) in mm	Average total throughfall (Plantation B) in mm	Average total throughfall in % Plantation A	Average total throughfall in % Plantation B
1	2.64	2.29	2.29	80.60	88.60
2	21.58	19.16	14.67	88.70	68.00
3	1.00	0.70	0.58	70.20	58.00
4	1.53	1.25	1.17	82.00	76.60
5	1.00	.082	0.79	82.00	79.20
6	2.97	2.48	2.04	83.60	68.80
7	26.28	25.79	22.76	98.11	87.20
8	7.90	7.54	6.45	95.50	81.60
9	7.72	6.86	6.27	88.90	81.20
10	2.81	2.51	1.90	89.60	67.51
Total	75.43	69.40	58.92		
Average (per storm)	7.54	6.94	5.892		

Research question 2 was answered using correlation analysis. This is a statistical method or procedure that is often used to investigate attributes of certain variables or entities that appear to occur together. Under such a situation, the interest may be to ascertain whether the variables are related and also predict if a significant relationship exists between them. In this case, the issue was to determine whether there is a relationship between gross precipitation and throughfall as regards the two tree plantations involved in this study.

Thus, a correlation analysis was undertaken to determine in the specific terms, whether there is any significant relationship between gross precipitation and throughfall in the two tree plantations, that is *Tectona* and *Gmelina* plantations, the result of which is presented in table 2.

Table 2. Correlation Analysis of the Two Tree Plantations

Variables	Correlations		
Gross precipitation	Gross precipitation 1.0	Throughfall (A) 0.998**	Through fall (B) 0.990**
Throughfall (Plantation A)	0.998** 0.000	0.000 1.00	0.000 0.996
Throughfall (Plantation B)	0.990** 0.000	0.996 0.000	1.000

**Correlation is significant at the 0.01 level (2-tailed test)

From the table, it is evident that there is a positive correlation between gross rainfall and throughfall in plantation A with a value of 0.998 and also a positive correlation between gross rainfall and throughfall in plantation B with a value of 0.990 all of which are significant at 0.01 level. All the correlations are not only positive but strong going by the values obtained in the table. The implication of this result is that gross precipitation has a strong relationship with throughfall in the two tree plantations. Indeed, it can be inferred that throughfall depends largely on gross precipitation such that there can never be throughfall without gross precipitation.

3. Conclusions

The study determined the variability of throughfall in two tree plantations on the campus of the University of Agriculture, Abeokuta, Southwest Nigeria. The study was able to establish that throughfall was more in the *Gmelina* plantation than *Tectona* plantation. Furthermore the study was able to establish the fact that there is a strong relationship between gross precipitation and throughfall in the two tree plantations. This implies that more attention need to be paid to the issue of interception loss as it is important in the study of water management in densely vegetation areas. Water loss through interception can be conserved through the practice of rainwater harvesting which can be stored for use in irrigation and mechanized agriculture particularly during dry spell period when there are short falls in rainfall. It is recommended that more studies be carried out in the area of interception as a way of establishing its influence on the availability of water in vegetated surfaces and its subsequent use for agriculture and other related activities.

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