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RESEARCH ARTICLE

Rain Natural Canopy Interception Measurements and Computations

Okolotu G. I. PhD.[1] and Oluka S. I.[2]

Department of Agricultural and Bioresource Engineering, Enugu State University of Science and Technology, Enugu, Nigeria

***Corresponding Authors:** Okolotu G.I., Department of Agricultural and Bioresource Engineering, Enugu State University of Science and Technology, Enugu, Nigeria*

ABSTRACT

Creating the practical novelty to bridge the lack of quantification and documentation of environmental data relative to rainfall natural canopy interception in the study area, other locations in Nigeria and beyond where such records are neglected, prompted the vitality of this research. Thus, the meteorological measurements of rainfall (above and within the rainfall canopies) of selected vegetations were obtained for the four geographical zones of Enugu State of Nigeria in West Africa, and prior the results, relevant computations were conducted to attain the desired canopy hydrological data. Free fall, throughfall, and stemflow were obtained through direct field measurements using their appropriate instruments for each canopy stand. Individual rainfall duration otherwise time were also recorded, while rainfall intensity, intercepted rainfall, and interception percentage were obtained using their various formulas. It was found that the canopy interception range between -3054.3mm to -11904.8mm in year 2016, and -4968.0mm to -28562.2mm in year 2017.

***Keywords**: Canopy Interception, Geographical Zones, Intercepted Rainfall, Enugu State*

Introduction

Rain natural canopy refers to the natural vegetative cover that the soil possesses as a shield from direct rainfall contact. Rain canopy otherwise vegetative cover is a conservative part of the hydrological (water) cycle where: 1, evaporation of water molecules from trees move to the atmosphere and in turn, falls as rain; 2, liquid water from direct rainfall flow to the soil through the leaves, branches, or the stem of trees. The rain canopy protects the soil from erosion of its particles and nutrients by reducing the kinetic energy potential of direct rainfall as well as direct sun rays intended to hit the forest floor. Dike, (2004) stated that 'the rays of the sun cause the soil to crack more especially during the dry season'. Rain canopy helps absorbs carbon dioxide, provide oxygen, and cleanses the air of pollutants. However, natural covers otherwise vegetation intercept rainfall and protect the soil more effectively when they exist in a closed canopy distance range. The major water measurements relative to the rain canopy are; the free fall, throughfall, and stemflow.

i. Free Fall: Freefall refers to the direct rainfall that is not obstructed within the canopy range. It is the precipitation not intercepted, which falls as direct rainfall (freely) on the forest floor. The standard instrument for the measurement of rainfall is the circular 203mm (8inch diameter) rain gauge which collects the rain into a graduated and a calibrated cylinder that can record up to 25mm of precipitation (Australian Bureau of meteorology, 2007).

ii. Throughfall: This is the amount of rainwater flow that drops directly from leaves to the forest floor within a canopy. It is the process that describes how wet leaves shed excess water onto the ground surface. This process is controlled by factors like; plant leaf and stem density, precipitation type, the intensity of precipitation, and duration of the precipitation event.

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iii. Stemflow: This is the flow of intercepted water down the trunk or stem of a plant. Stemflow along with throughfall are responsible for the transfer of precipitation and nutrients from the canopy to the soil. The most common direct measurement of stemflow is by bonding of bisected PVC or another plastic tubing around the circumference of the tree trunk, connected and funneled into a graduated cylinder for manual collection or into a tipping bucket rain gauge for automatic collection. The tubing may be wrapped multiple times around the trunk to ensure complete collection.

Stemflow determining factors include Precipitation features like rainfall continuity, rain angle, rainfall intensity; stand characteristic (the overall structure of the forest stand factors like species composition, canopy structure, stand density, diurnality e.g., branches are heavier in the morning and lighter in the afternoon, seasonality); species factors (leaf shape e.g., concave or convex, branch angle, crown size, bark smoothness and absorption ability, flow path obstructions).

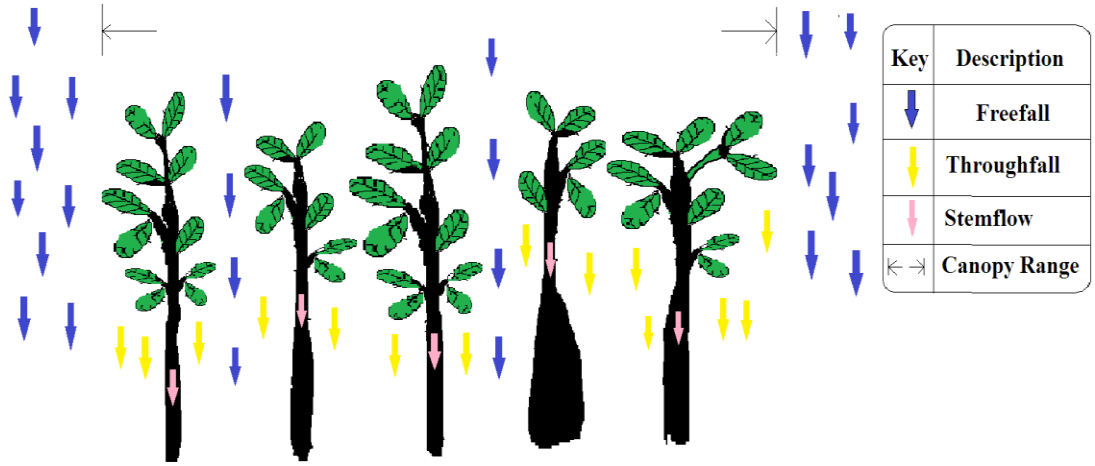

Figure 1: Rainfall Canopy Water Flow Diagram

The major factors that affect rainfall canopy interception are; leaf area index (Some trees e.g., Conifers, have greater interception than other trees e.g., hardwoods since they have more surface area to intercept rainfall), type of leaves (concave or convex shape, short or long leaves), type of vegetation (forest areas have broad leaves and not flat leaves for easy water collection). Critchley and Siegert, (1991) noted that "Amount of rain lost to interception storage depends on the kind of vegetation and its growth stage"), type of fall (Most snowfalls off the tree by wind or melts, hence snowfall does not result in any notable amount of measurement accuracy, while rainfall has a liquid form which is directly measurable with high accuracy using gauges), and through-fall effect (heavy sideward wind direction which could alter the vertical movement of rainfall, as well as leaves position displacement). Canopy height and gaps in the canopy are also influencing factors of canopy interception. Conceptually, canopy cover is the vertical projection of plant foliage onto a horizontal surface; in practice, measurement of canopy cover assess either foliage, foliage plus stems, or canopy perimeters (Fiala et. al. 2006)

The most often method used for measuring canopy interception is by measuring rainfall above the canopy and subtracting stem-flow and through-fall. This method cannot be used in snow regions, so, a more suitable method by Hancock and Crowder (1979) was developed by use of cantilever effect of branches for such areas. If the leaf on a branch holds water, it becomes heavy and will bend. Thus by measuring the displacement, the amount of water intercepted is determined. Huang et. al. refined this method in 2005 by making use of strain gauges. However it will be laborious to measure all forest trees, hence only a few single branches of trees are ideal for this method.

2. Materials

The materials used for this study include;

The Study Area

The study area, otherwise the ground base upon which this research work was conducted in Enugu state. Enugu state is one of the six (6) states located in the southeastern part of Nigeria, West Africa. It is named after the land

structure as “Enugu” which is translatable in English as “hilltop”. The area has an extreme hill of 1,000 meters elevation (3,300 ft). Enugu state vegetation is generally categorized as a tropical rainforest. Nsa et. al. (2021) noted that Enugu has different vegetation types ranging from the tropical rainforest in the south to open grassland and savannah in the north.

Figure 2: Location of Enugu state in the Map of Nigeria (Atlas, 2016)

Other materials include; 64 canopy trees (cash crop trees of Mango used as a medium upon which intercepted rainfall were collected), 208 pieces of plywood stands (for placement of gauges for freefall, throughfall, and stemflow rainfall collection), plastic pipes (used for rainfall water channeling for stemflow rainfall collection), 40 pieces of 25 liters and 24 pieces of 20litre plastic containers (used for stemflow rainwater storage), 208 pieces of a standard rain gauge (used for rainfall collection and measurement), 5mp digital video camera (used for obtaining site images and time observations), workbook (used for data documentation), rain boots and raincoats (used as foot and body wears/rain guard), umbrella (used as a rain cover for site observations during rainfall events).

3. Methods

Canopy measurements were carried out in four geographical zones of the study area. Freefall data were obtained using the rain gauges placed outside the canopy coverage. Through-fall data were obtained using the rain gauges, appropriately placed on the plywood stand under the leaves of the branches within the canopy coverage range but a few distances away from the tree bole to obtain and measure rainwater falling only directly from the leaves. Thus, four (4) gauges were placed under a tree canopy and their average throughfall measurement value was recorded for interception computations. Stem flow data were obtained by volumetric measurement of rainwater (using the rain gauge cylinder) in the plastic water collectors connected through plastic pipe tubing attached around the tree trunk or bole of selected canopies. The field measurements of rainfall data obtained in ml were afterward converted and recorded in mm (which is usable in erosion computations) i.e., the values of water collected in ml were multiplied by 10 and both divided by the area of the size of the opening of the rain gauge where the rainwater goes into the gauge. This can be summarized in equation 3.1 below;

$$Ar = Vc/Ac \times \lambda/1 \qquad \text{----- (Eq. 3.1)}$$

Where;

Ar = Amount of rainfall (mm).

Vc = volume of water collected by the gauge (ml).

Ac = Area of rain catcher of gauge (cm).

$\boldsymbol{\lambda}$ = constant variable for conversion. $\boldsymbol{\lambda}$ is equal to 10 for milliliter (ml) to millimeter (mm). $\boldsymbol{\lambda}$ has no unit.

Freefall (FF), throughfall (TF), stemflow (SF), and Time (T) were obtained through their meteorological process of rain collection. Intercepted rainfall (IR) and Rainfall intensities (I) were obtained through mathematical computations prior to the above mentioned meteorological data using the appropriate formulas: Intercepted Rainfall equals the difference between freefall rain and rainfall measurements within the canopies of trees as shown in equation 3.2 below;

IR = FF – (TF + ST) ----- (Eq. 3.2)

Where;

IR = Intercepted rainfall by canopies (mm)

FF = Free fall (mm).

TF = Throughfall (mm)

ST = Stemflow of rainfall (mm).

I = FF x T ----- (Eq. 3.3)

Where;

I = Rainfall Intensity (mmhr-1)

FF = Freefall of rain (mm)

T = Rainfall duration or Time (hr-1).

Interception percentage ratio, IP is expressed in equation 3.4 below;

IP=(IR X 100)/FF ……(Eq.3.4)

Where;

IP = Interception percentage (%)

IR = Intercepted rainfall by canopies (mm)

FF = Freefall of rain (mm).

The measured hydrological data (within and outside the rainfall canopy), as well as relevant computations, are presented in tables 3.1 to 3. 8.

Table 3.1: The year 2016 Monthly Rainfall Data for Enugu North (Nsukka)

Month	Freefall, FF (in mm)	Throughfall, TF (in mm)	Stem flow, SF (in mm)	Time, T (in hr^{-1})	Rainfall intensity, I (in $mmhr^{-1}$)	Intercepted rainfall, IR (in mm)	Interception percentage, IP (in %)
January	0.0	0.0	0.0	0.00	0.00	0.0	0.0
February	0.0	0.0	0.0	0.00	0.00	0.0	0.0
March	0.0	0.0	0.0	0.00	0.00	0.0	0.0
April	0.0	0.0	0.0	0.00	0.00	0.0	0.0
May	0.0	0.0	0.0	0.00	0.00	0.0	0.0
June	346.2	240.7	1932.2	2.24	775.49	-1826.0	-527
July	531.4	417.6	1693.8	4.62	2455.07	-1580.2	-297
August	916.4	812.6	4603.7	5.45	4994.38	-4500.0	-491
September	613.3	496.9	1600.3	2.91	1784.70	-1594.0	-260

October	617.7	500.7	2256.1	6.70	4138.59	-2139.0	-346
November	0.0	0.0	0.0	0.00	0.00	0.0	0.0
December	0.0	0.0	0.0	0.00	0.00	0.0	0.0
Annual/∑	3025.0	2468.5	12086.1	21.92	14148.23	-11639.2	-385

Table 3.2: The year 2017 Monthly Rainfall Data for Enugu North (Nsukka)

Month		**Free fall, FF (in mm)**	**Through fall, TF (in mm)**	**Stem flow, SF (in mm)**	**Time, T (in hr^{-1})**	**Rainfall intensity, I (in $mmhr^{-1}$)**	**Intercepted rainfall, IR (in mm)**	**Interception percentage, IP (in %)**
January		0.0	0.0	0.0	0.00	0.00	0.0	0.0
February		0.0	0.0	0.0	0.00	0.00	0.0	0.0
March		0.0	0.0	0.0	0.00	0.00	0.0	0.0
April		183.8	119.7	689.1	2.17	398.85	-625.0	-340
May		463.6	367.2	1456.2	1.97	913.29	-1359.2	-293
June		823.4	854.8	2967.1	3.07	2527.84	-2998.0	-364
July		842.1	512.6	3013.1	5.30	4463.13	-2685.0	-319
August		647.4	323.4	1408.6	3.40	2201.16	-1084.0	-167
September		793.4	625.1	3153.0	8.75	6942.25	-2985.0	-376
October		392.8	487.0	1824.6	5.11	2007.21	-1919.8	-489
November		0.0	0.0	0.0	0.00	0.00	0.0	0.0
December		0.0	0.0	0.0	0.00	0.00	0.0	0.0
Annual/∑		4146.5	3289.8	14511.7	29.77	19453.73	-13656.0	-329

Table 3.3: The year 2016 Monthly Rainfall Data for Enugu South (Awgu)

Month	**Freefall, FF (in mm)**	**Throughfall, TF (in mm)**	**Stem flow, SF (in mm)**	**Time, T (in hr^{-1})**	**Rainfall intensity, I (in $mmhr^{-1}$)**	**Intercepted rainfall, IR (in mm)**	**Interception percentage, IP (in %)**
January	0.0	0.0	0.0	0.00	0.00	0.0	0.0
February	0.0	0.0	0.0	0.00	0.00	0.0	0.0
March	0.0	0.0	0.0	0.00	0.00	0.0	0.0
April	874.8	432.2	1267.0	7.33	6412.28	-724.4	-83
May	1002.7	844.2	2772.4	12.93	12964.91	-2613.9	-261
June	820.1	664.8	2060.7	10.30	8447.03	-1905.4	-232
July	537.5	279.5	894.2	5.06	2719.75	-636.2	-118
August	474.0	235.1	1390.1	3.98	1886.52	-1151.2	-243
September	497.9	401.0	890.5	7.70	333.83	-793.6	-159
October	561.9	487.1	1220.8	4.51	2534.17	-1146.0	-204
November	0.0	0.0	0.0	0.00	0.00	0.0	0.0
December	0.0	0.0	0.0	0.00	0.00	0.0	0.0
Annual/∑	4768.9	3343.9	10495.7	51.81	35298.49	-8970.7	-188

Table 3.4: The year 2017 Monthly Rainfall Data for Enugu South (Awgu)

Month	**Freefall, FF (in mm)**	**Throughfall, TF (in mm)**	**Stem flow, SF (in mm)**	**Time, T (in hr^{-1})**	**Rainfall intensity, I (in $mmhr^{-1}$)**	**Intercepted rainfall, IR (in mm)**	**Interception percentage, IP (in %)**
January	0.0	0.0	0.0	0.00	0.00	0.0	0.0
February	0.0	0.0	0.0	0.00	0.00	0.0	0.0
March	387.9	290.7	708.6	2.58	1000.78	-611.4	-158
April	402.6	285.7	551.8	4.79	1928.45	-434.9	-108
May	321.5	179.8	216.8	3.38	1086.67	-75.1	-23
June	463.7	325.6	916.1	4.59	2128.38	-778.0	-168
July	713.2	523.5	1441.5	9.06	6461.59	-1251.8	-176
August	217.2	158.6	492.8	7.41	1609.45	-434.3	-200

September	426.9	335.2	458.9	4.48	1912.51	-339.6	-80
October	455.3	368.2	832.2	4.24	1930.47	-745.1	-164
November	224.8	165.2	356.7	1.52	341.70	-297.1	-132
December	18.2	16.1	2.8	0.31	5.64	-0.7	-4
Annual/∑	3631.3	2648.6	5978.2	42.36	18405.64	-4968.0	-137

Table 3.5: The year 2016 Monthly Rainfall Data for Enugu East (Capital)

Month	Freefall, FF (in mm)	Throughfall, TF (in mm)	Stem flow, SF (in mm)	Time, T (in hr^{-1})	Rainfall intensity, I (in $mmhr^{-1}$)	Intercepted rainfall, IR (in mm)	Interception percentage, IP (in %)
January	0.0	0.0	0.0	0.00	0.00	0.0	0.0
February	0.0	0.0	0.0	0.00	0.00	0.0	0.0
March	0.0	0.0	0.0	0.00	0.00	0.0	0.0
April	0.0	0.0	0.0	0.00	0.00	0.0	0.0
May	0.0	0.0	0.0	0.00	0.00	0.0	0.0
June	711.3	339.6	2352.4	7.90	5619.27	-1980.7	-278
July	734.5	422.1	4265.5	10.85	7969.33	-3953.1	-538
August	1004.3	472.1	3895.8	12.03	12081.73	-3363.6	-335
September	951.3	505.0	1965.6	10.21	9712.77	-1519.3	-160
October	372.9	212.7	960.1	2.44	909.88	-799.9	-215
November	97.3	69.9	315.6	0.94	91.46	-288.2	-296
December	0.0	0.0	0.0	0.00	0.00	0.0	0.0
Annual/∑	3871.6	2021.4	13755.0	44.37	36384.44	-11904.8	-307

Table 3.6: The year 2017 Monthly Rainfall Data for Enugu East (Capital)

Month	Freefall, FF (in mm)	Throughfall, TF (in mm)	Stem flow, SF (in mm)	Time, T (in hr^{-1})	Rainfall intensity, I (in $mmhr^{-1}$)	Intercepted rainfall, IR (in mm)	Interception percentage, IP (in %)
January	0.0	0.0	0.0	0.00	0.00	0.0	0.0
February	0.0	0.0	0.0	0.00	0.00	0.0	0.0
March	0.0	0.0	0.0	0.00	0.00	0.0	0.0
April	0.0	0.0	0.0	0.00	0.00	0.0	0.0
May	0.0	0.0	0.0	0.00	0.00	0.0	0.0
June	42.9	34.1	627.0	0.51	21.88	-618.2	-1,441
July	834.4	522.7	5531.8	15.58	12999.95	-5220.1	-626
August	951.6	493.0	4088.0	12.29	11695.16	-3629.4	-381
September	1058.1	485.3	4059.0	13.56	14347.84	-3486.2	-329
October	623.7	520.0	3213.5	9.42	5875.25	-3109.8	-499
November	25.3	5.1	28.3	0.29	7.34	-8.1	-32
December	0.0	0.0	0.0	0.00	0.00	0.0	0.0
Annual/∑	3536.0	2060.2	17547.6	51.65	44947.42	-16071.8	-455

Table 3.7: The year 2016 Monthly Rainfall Data for Enugu West (Udi)

Month	Freefall, FF (in mm)	Throughfall, TF (in mm)	Stem flow, SF (in mm)	Time, T (in hr^{-1})	Rainfall intensity, I (in $mmhr^{-1}$)	Intercepted rainfall, IR (in mm)	Interception percentage, IP (in %)
January	0.0	0.0	0.0	0.00	0.00	0.0	0.0
February	0.0	0.0	0.0	0.00	0.00	0.0	0.0
March	0.0	0.0	0.0	0.00	0.00	0.0	0.0
April	0.0	0.0	0.0	0.00	0.00	0.0	0.0
May	0.0	0.0	0.0	0.00	0.00	0.0	0.0
June	477.3	295.8	1192.9	4.78	2281.49	-1011.4	-212
July	263.2	193.7	621.9	1.13	297.42	-552.4	-210

August	296.1	219.0	649.2	1.90	562.59	-572.1	-193
September	217.3	163.6	927.9	1.57	341.16	-874.2	-402
October	91.5	66.9	53.3	0.94	86.01	-28.7	-31
November	197.0	136.4	76.1	1.14	224.58	-15.5	-8
December	0.0	0.0	0.0	0.00	0.00	0.0	0.0
Annual/∑	1542.4	1075.4	3521.3	11.46	3793.25	-3054.3	-198

Table 3.8: The year 2017 monthly Rainfall Data for Enugu West (Udi)

Month	Freefall, FF (in mm)	Throughfall, TF (in mm)	Stem flow, SF (in mm)	Time, T (in hr^{-1})	Rainfall intensity, I (in $mmhr^{-1}$)	Intercepted rainfall, IR (in mm)	Interception percentage, IP (in %)
January	113.1	84.8	221.9	1.50	169.65	-193.6	-171
February	0.0	0.0	0.0	0.00	0.00	0.0	0.0
March	91.9	67.7	248.2	0.46	42.274	-224.0	-244
April	1216.3	893.3	5049.9	19.11	23243.49	-4726.9	-389
May	1014.7	745.6	2498.4	10.08	10228.18	-2229.3	-220
June	1743.8	1276.7	4920.5	12.81	22338.08	-4453.4	-255
July	2482.0	1817.3	7312.3	17.42	43236.44	-6647.6	-268
August	1692.8	1324.6	3564.4	10.37	17554.34	-3196.2	-189
September	2396.8	1752.0	5104.1	12.89	30894.75	-4459.3	-186
October	1689.8	1217.5	2904.2	9.96	16830.41	-2431.9	-144
November	0.0	0.0	0.0	0.00	0.00	0.0	0.0
December	0.0	0.0	0.0	0.00	0.00	0.0	0.0
Annual/∑	12441.2	9179.5	31823.9	94.60	164537.61	-28562.2	-230

4. Results

The annual results of rainfall data within and outside the canopies for the zones are presented in tables 4.1, and 4.2 below

Table 4.1: Annual 2016 Rainfall Data for Enugu State

Zone	Freefall, FF (in mm)	Throughfall, TF (in mm)	Stem flow, SF (in mm)	Time, T (in hr^{-1})	Rainfall intensity, I (in $mmhr^{-1}$)	Intercepted rainfall, IR (in mm)	Interception percentage, IP (in %)
Enugu North (Nsukka)	3025.0	2468.5	12086.1	21.92	14148.23	-11639.2	-385
Enugu South (Awgu)	4768.9	3343.9	10495.7	51.81	35298.49	-8970.7	-188
Enugu East (Capital)	3871.6	2021.4	13755.0	44.37	36384.44	-11904.8	-307
Enugu West (Udi)	1542.4	1075.4	3521.3	11.46	3793.25	-3054.3	-198

Table 4.2: Annual 2017 Rainfall Data for Enugu state

Zone	Free fall, FF (in mm)	Throug h fall, TF (in mm)	Stem flow, SF (in mm)	Time, T (in hr^{-1})	Rainfall intensity, I (in $mmhr^{-1}$)	Intercepted rainfall, IR (in mm)	Interception percentage, IP (in %)
Enugu North (Nsukka)	4146.5	3289.8	14511.7	29.77	19453.73	-13656.0	-329
Enugu South (Awgu)	3631.3	2648.6	5845.6	42.36	18405.64	-4968.0	-137
Enugu East (Capital)	3536.0	2060.2	17547.6	51.65	44947.42	-16071.8	-455
Enugu West (Udi)	12441.2	9179.5	31823.9	94.60	164537.61	-28562.2	-230

The monthly Interception variation diagram for 2016 and 2017 and the annual variation curve for freefall and interception are presented in figures 3, 4, and 5 below.

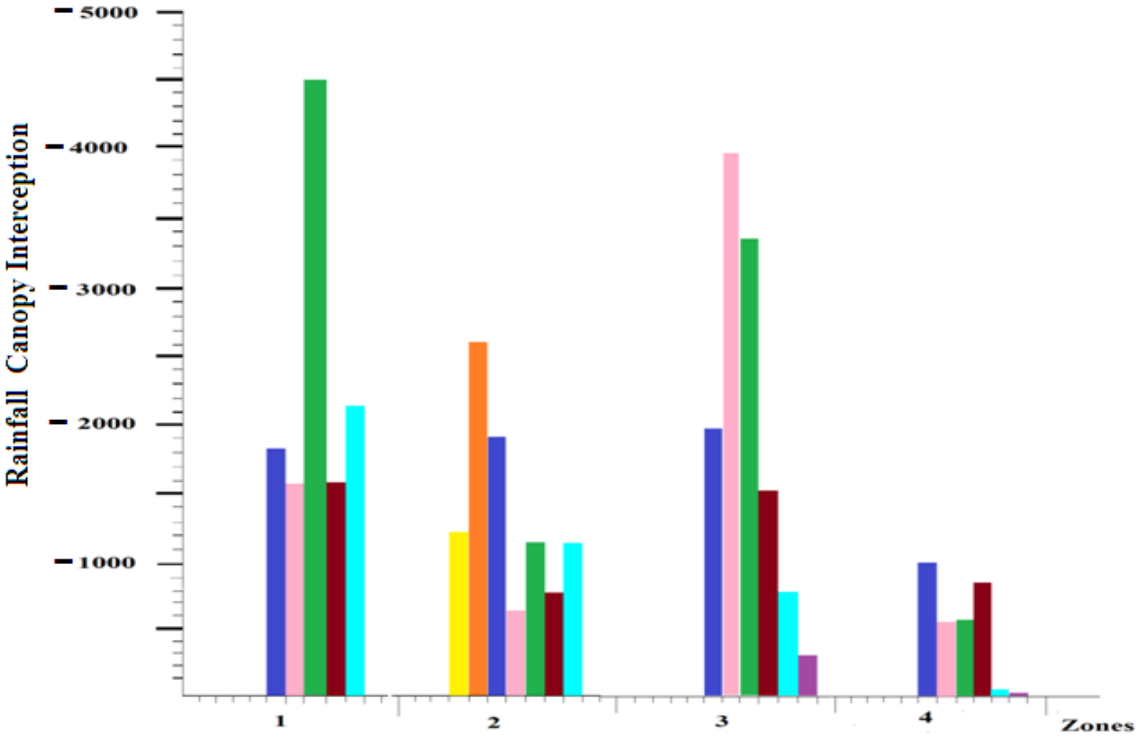

Figure 3: Monthly Interception Variation Diagram for the Year 2016

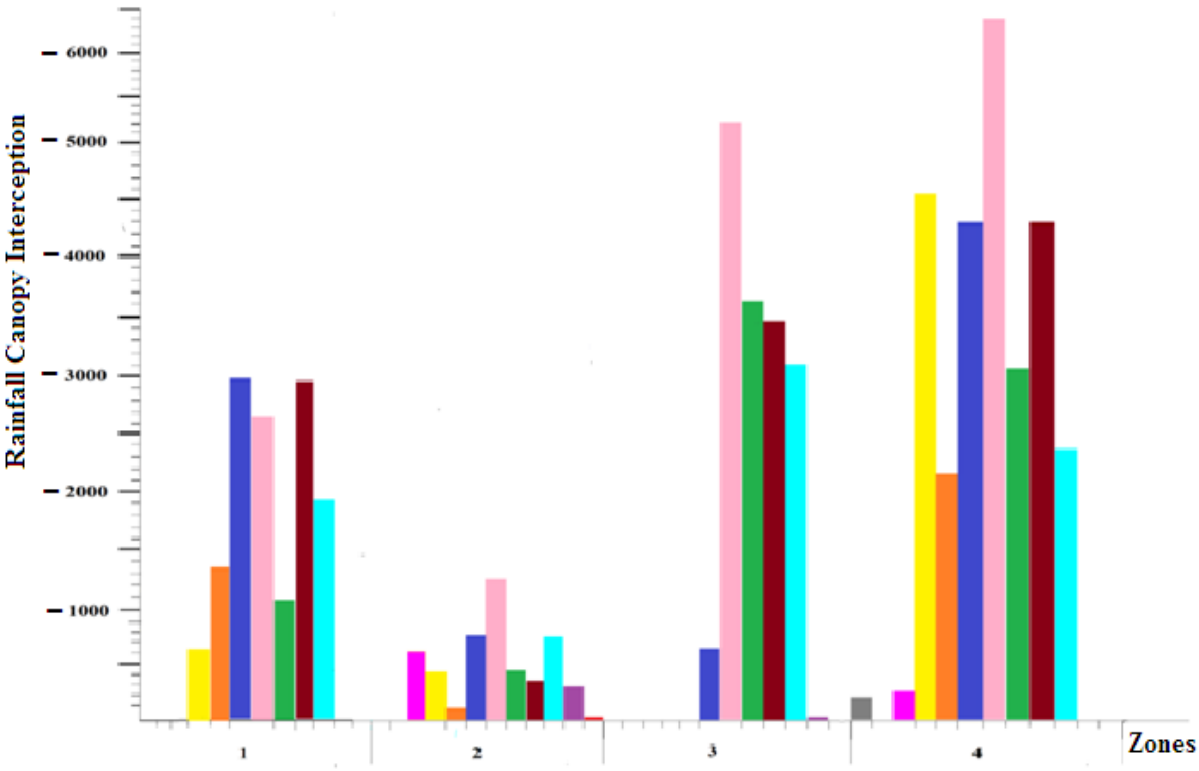

Figure 4: Monthly Interception Variation Diagram for the Year 2017

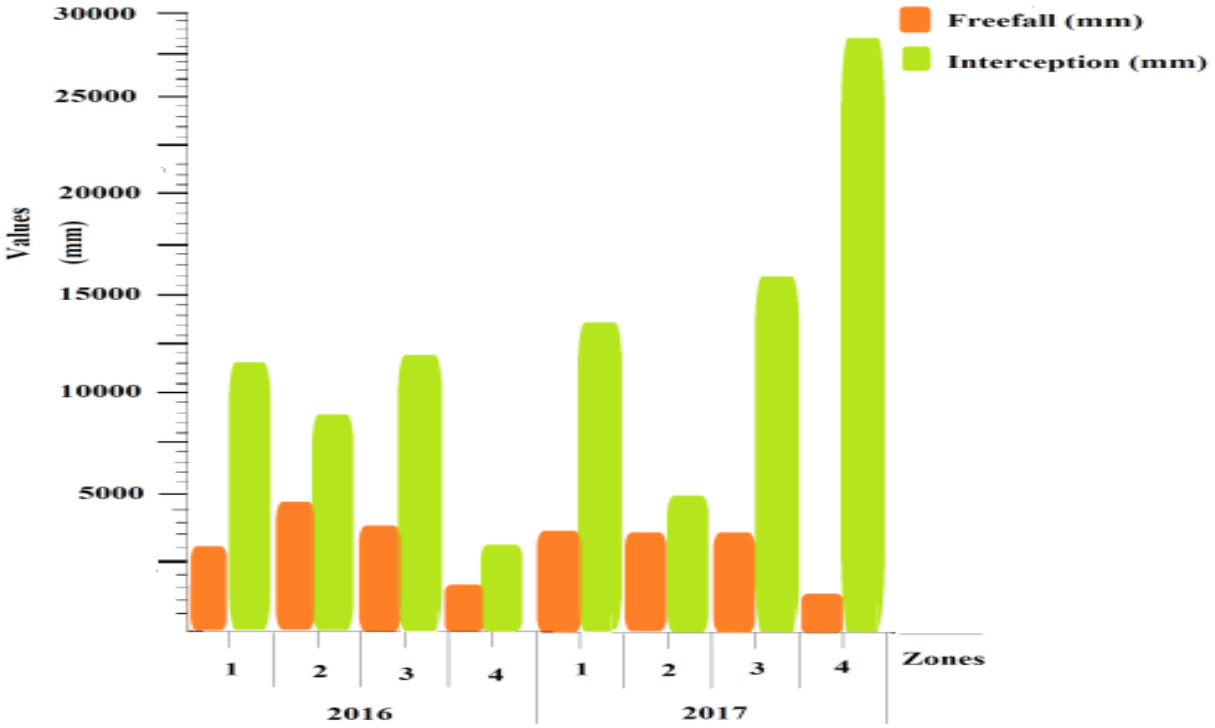

Figure 5: Annual Variation Curve for Freefall and Interception

5. Discussion

From the Interception variation diagrams in Figures 1 and 2, more rainwater was intercepted in August and June (zone 1), May and July (zone 2), July and July (zone 3), and June and July (zone 4) in the year 2016 and 2017 respectively. These periods of the months fall within the peak rainy season of the study area.

The obtained interception results represent the precipitation intercepted before reaching the soil. Certain amounts of precipitated rain are also lost to the atmosphere a few hours upon reaching the soil through evaporation. This is regarded as forest floor interception described by Gerrits (2010) as "the part of the throughfall that is temporarily stored in the top layer of the forest floor and successively evaporated within a few hours or days during and after the rainfall event". Forest floor interception can be obtained using the simple threshold model described by Savenije (1997) as below;

$E_{int} = \min (P_d, D)$ ..... (Eq. 5.1)

Gerrits *et. al*. (2007) noted that this model describes the daily interception as a threshold process with Pd the daily rainfall (LT^{-1}) and D the daily interception threshold (LT^{-1}).

6. Conclusion

The hydrologic canopy interception in Enugu State zones ranges between -3,054.3mm to -11,904.8mm in the year 2016, and -4,968.0mm to -28,562.2mm in the year 2017.

7. Recommendation

Replication of this research process will aid the acquisition of more annual data (10 years and above) for future prediction of canopy interceptions, valuable for hydrological and meteorological purposes of great importance in widening the scope of weather and climatic studies of our environment.

References

Atlas, 2016. Nigeria, World Map. Africa. Nigeria World Map. p 1.

Australian Bureau of meteorology (2007). Observation of rainfall. Australian government bulletin. p 2.

Critchley, W., and Siegert, K., (1991). Water Harvesting. A Manual for Design and Construction of Water Harvesting Schemes for Plant Production. Food and Agriculture Organization of the United Nations – Rome. p 10.

Dike M.C. (2004). Assessing the ecological status of woody plant species at eroded sites of Abia and Imo states, Nigeria. p 1.

Fiala A.C.S., Garman S.L., and Gray A.N., (2006). Comparison of five canopy estimation techniques in the western Oregon cascade. *Forest Ecology and Management*, 232: 190.

Gerrits, A.M.J. (2010). The role of interception in the hydrological cycle. VSSD, Delft, the Netherlands. p 8.

Gerrits, A.M.J., Savenije, H.H.G., Hoffmann, L., and Pfister, L., (2007). New technique to measure forest floor interception – an application in a beech forest in Luxembourg. *Hydrol. Earth Syst. Sci*. 11: 698.

Hancock N.H., Crowder J.M., (1979). A technique for the direct measurement of water storage on the forest canopy. *Journal of Hydrology,* 41: 105-122.

Huang, Y.S., Chen, S.S., Lin, T.P. (2005). Continuous monitoring of water loading of trees and canopy rainfall interception using the strain gauge method. *Journal of Hydrology*, 311: 1-7.

Nsa I.Y., Oyebanji O.O., Igbinigie E.E, and Odunsi A.A. (2021). Floral Distribution of a Sub-Bituminous Coal Dumpsite in Enugu, Nigeria*. Frontiers in Ecology and Evolution*, 9(6).

Savenije, H.H.G., (1997). Determination of evaporation from a catchment water balance at a monthly time scale. *Hydrol. Earth System Sci.*1: 96.