

## Precipitation Pathway Channels as Mechanism for Nutrients Cycling in Diospyros Crass Flora (Hiern) Plantation in Abia State, Nigeria

<sup>1</sup> E. E. Offiong, <sup>2</sup> I. B. Nsien, <sup>2</sup> A. N. Ejizu & <sup>2</sup> E. E. Eric

<sup>1</sup> Department of Forestry and Wildlife Resources Management, University of Calabar  
Calabar, Nigeria

<sup>2</sup> Forestry Research Institute of Nigeria, P.M.B.5054 Ibadan, Oyo State, Nigeria

Corresponding Author: [E. E. Offiong](#)

**Abstract: Problems:** Several factors affect the amount and nutrient content of through fall and other precipitation pathways. These include storm size and intensity, length of time between storms, season, latitude, proximity to sources of nutrients, stand age, forest type, site fertility and insect consumption. This paper focused on the determination of macro-nutrient elements accretion to the soil through precipitation pathways overtime at Diospyros crass flora plantation in the Humid Forest Research Station, Forestry Research Institute Okwuta-Ibeku Umuahia, Abia State, Nigeria. **Approach:** A 3 x 9 x 2 split-split plot experiment in a randomised complete block design (RCBD) with three replications/blocks was used to study the nutrient cycling contents of three precipitation pathways overtime. The first factor comprised three precipitation pathways, namely: rainfall, through fall and stemflow. The second factor was sampling periods which comprised of 9 months (March – November) in 2016 and 2017. The study of throughfall was carried out in each of the 10m x 25m blocks using nine plastic collectors each in a 40cm diameter plastic funnel. The third factor was two study years (2016 and 2017). Rainfall was sampled with three plastic collectors, each 45cm above the ground in an open field adjacent or opposite to the plantation. The plastic collectors were randomly positioned under the canopies of D. crass flora plantation in each block/replicate. This rainfall collection method served as control for rainfall outside the D. crassiflora plantation. Stem flow was studied using a hose of 2cm in diameter, attached to the stem of the tree and connected to an enclosed plastic collector. Collection of stemflow volumes took place every day that rainfall occurred. At each collection, the water was measured with a measuring cylinder. The water collected per precipitation pathways was stored in a deep freezer and was later taken to Soil Laboratory for chemical analysis to determine the nutrients. Data were analyzed using the Fisher's Least Significant Different (F-LSD) at  $p \leq 0.05$ . **Findings:** Results of the study revealed that rainfall started by March and ended by November in 2016 and 2017. The amount or quantity of incipient precipitations varies from one ecosystem to another. However, the precipitation pathways showed that stemflow had significantly higher water quantity (1397.11 and 1594.00) than the control (435.33 and 433.00) and throughfall (374.11 and 327.00) channels in the year 2016 and 2017 respectively. Result gathered from the experiment carried out in the Laboratory confirmed that The various precipitation pathways (incipient precipitation/rainfall, throughfall and stemflow) obtained from D. crassiflora Plantation contained ten mineral elements, such as pH, nitrogen sodium, calcium, magnesium, chlorine, phosphorus, potassium, iron, and lead. **Conclusion:** Irrespective of the month which precipitation pathways occurred, it is always associated with nutrients, though the concentrations of these mineral nutrients depend on the intensity of rainfall and leach-ability of plant either by throughfall or stemflow pathways. The amount of precipitation during onset of rain (March - May) and towards ending of rain (October-November) in both years of the study were relatively small as compared to the months of June - September in 2016 and 2017.

**Keywords:** Precipitation pathways, Stemflow, Throughfall, Rainfall, Mineral element, Umuahia, Abia State, Humid forest, Research Station, Nigeria.

## Introduction

Naturally large quantities of nutrients are added to ecosystems from the atmosphere. This addition is done either through incipient precipitation (rainfall) or by a number of biological processes [1]. Rainfall is known to be commonest means where precipitations are distributed in our environment mostly in tropical region[2]. Precipitation associated with rain attracts a lot of mineral elements that is often deposited in the soil. Rain water constitutes an important pathway for nutrient transfer to the forest floor [3]. Rain that reaching forest floor is partition into three major precipitation pathways, namely: incident precipitation (rainfall), throughfall and stemflow as it passes through the forest canopy. Irrespective of the pathways, a lot of fractions and interception occur between tree canopies and forest floor both in the natural or artificial ecosystem. Interception loss is defined as the fraction of rainfall intercepted by the canopy and then evaporates back into the atmosphere [3]. Bulk precipitation can be partitioned into interception loss, throughfall, and stemflow as it passes through the forest canopy. The latter two fractions both reach the ground surface as understory rainfall [4-5, 3].

The quantity of precipitation falling on forests is affected during a brief but significant interaction with the surfaces of plants, resulting in the transfer of additional minerals to the soil [6]. Quantity and distribution of throughfall and stemflow depend on bark smoothness, stem diameter, branch angle, canopy structure such as crown density and open spaces in the canopy [7]. Obviously, trees with dropping branches produce more throughfall at the canopy perimeters, while those with large crown emergent, smooth branch and raised branches produce more stemflow. Several factors affect the amount and nutrient content of throughfall and other precipitation pathways. These include storm size and intensity, length of time between storms, season, latitude, proximity to sources of nutrients, stand age, forest type, site fertility and insect consumption [7]. Nutrient's concentration in precipitation varies from place to place and species to species depending on the origin of air masses. Precipitation from maritime air masses contains a higher content of Na annually than in the continental air masses [7].

Stemflow along with throughfall are responsible for the transfer of precipitation and nutrients from the plant cover to the soil. The chemical composition of precipitation intercepted by the canopy is enhanced by wash-off of dry deposition collected by the canopy and foliar leaching of nutrients into rainwater [8]. The extent to which dry deposition of foliar leaching enhances the nutrient status of intercepted precipitation is a function of leaf and canopy morphology and nutrient status, as well as regional climatic and environmental conditions. This paper focuses on determination of macro-nutrient elements accretion to the soil through precipitation pathways overtime at D. crassifloraplantation within a given period.

## Materials and Methods

### Description of Study Sites

The study precipitation pathway channels as mechanism for nutrients cycling in *D. crassiflora* plantation in Umuahia, Abia State- Nigeria was carried out in the Humid Forest Research Station, Forestry Research Institute of Nigeria (FRIN). Okwuta-Ibeku, Umuahia is located at kilometres five (km 5) along the Umuahia / IkotEkpene highway. It is within the lowland rainforest [9]. Okwuta-Ibeku, Umuahia lies between longitudes  $7^{\circ}32'$  and  $8^{\circ}10'$  E and latitude  $5^{\circ}29'$  and  $6^{\circ}14'N$  of the equator and on altitude of 122m (Source: Metrological Station, National Root Crop Research Institute (NRCRI) Umudike, Nigeria). The soil type is Ultisol which ranges from sandy loam to sandy clay-loam (Source: Soil Division, NRCRI, and Umudike). Umuahia has the following mean annual climatic data: rainfall: 2238mm, maximum and minimum temperatures:  $32^{\circ}C$  and  $23^{\circ}C$  respectively, and relative humidity: 65 -80% (Source: Metrological Station, NRCRI, Umudike, Nigeria).

### Methods of Data Collection

A  $3 \times 9 \times 2$  split- split plot experiment in a randomised complete block design (RCBD) with three replications/blocks was used to study the nutrient cycling contents of three precipitation pathways overtime at the *D. crassifloraplantation* in the Humid Forest Research Station, Forestry Research Institute of Nigeria, Okwuta-Ibeku, Umuahia, Abia State. The first factor comprised three precipitation pathways, namely: rainfall, throughfall and stemflow. The second factor was sampling periods which comprised of 9 months (March – November) in 2016 and 2017. The study of throughfall was carried out in each of the 10m x 25m blocks using nine plastic collectors each in a 40cm diameter plastic funnel. The third factor was two study years (2016 and 2017).

Rainfall was sampled with three plastic collectors, each 45cm above the ground in an open field adjacent or opposite to the plantation. The plastic collectors were randomly positioned under the canopies of *D. crassifloraplantation* in each block/replicate. This rainfall collection method served as control for rainfall outside the *D. crassiflora* plantation. Stemflow was studied using a hose of 2cm in diameter, attached to the stem of the tree and connected to an enclosed plastic collector. Nine plastic collectors were used and randomly positioned. Collection of stemflow volumes took place every day that rainfall occurred. At each collection, the water was measured with a measuring cylinder. The water collected per precipitation pathways was stored in a deep freezer at FRIN, Okwuta –Ibeku, Umuahia and was later taken to the Soils Laboratory of the National Root Crop Research Institute (NRCRI), Umudike for chemical analysis.

The data obtained from three precipitation pathways study from laboratory test were statistically analysed using the Fisher's Least Significant Different (F-LSD) at  $p \leq 0.05$  according to the procedures of [10] and [11]. Water samples of the rainfall, throughfall and stemflow were later analysed in the laboratory to determine the nutrients stated below:

### **Hydrogen ion concentration (pH) and Nitrogen (N)**

The hydrogen ion concentration (pH) was measured electronically on a direct reading pH meter using a glass of electrode with a saturated potassium chloride- calomel reference electrode [12]. The pH meter was calibrated with standard pH buffer solution of pH 4.0, pH 7.0 and pH 9.0; 50ml water sample was pipetted into a 100ml clean beaker and the electrode was dipped into the beaker. Nitrogen contents in the various precipitation pathways were determined by the semi- micro distillation method- the Kjeldahl method [13]. 100ml of water sample was distilled with Markhan's distillation apparatus. 50ml distillate was collected over 10ml of 4% H<sub>2</sub>BO<sub>3</sub> using Ma-zua -zaga indicator. The distillate was titrated with 0.02 NH<sub>2</sub>SO<sub>4</sub>.

### **Phosphorus (P) and Calcium (Ca)**

Phosphorus was determined spectrophotometrically [14, 15]. The ethylene diamine tetracetic acid (EDTA) versenate complexometric titration method was used to determine Ca contents in each precipitation pathway [16].

### **Potassium (K) and Sodium (Na)**

Potassium and sodium were determined by direct reading with the flame emission photometer [17].

### **Chlorine (Cl) and Iron (Fe)**

This was determined titrimetrically [12]. Ten (10) ml water sample was pipetted into a 150ml conical flask. Three drops of potassium chromate were added into the flask as an indicator. The water sample was titrated with 0.02N AgNO<sub>3</sub> to a reddish brown end point. Iron (Fe) was analysed using the atomic absorption spectrophotometer (AAS) with UNICAM 929 spectrophotometer equipment according to the procedures of [16].

### **Magnesium (Mg) and Lead (Pb)**

Magnesium was also determined using the EDTA versenate complexometric titration method in each precipitation pathway [16]. Lead and cadmium were determined in water sample using the method of [18, 19]. 50ml of water samples of Pb was individually placed in a 500ml beaker. Each sample of Pb and Cd was heated in a water bath at 100°C to concentrate the sample to 40ml. 5ml, 1.0ml HCl solution was then added to the concentrated water and brought to 50ml volumetric flask. The levels of Pb and Cd were determined using the atomic absorption spectrophotometer [18, 19].

## **Results and Discussions**

### **Quantity of precipitation channels in D. crassiflora Plantation in 2016 and 2017**

Table 1 shows the quantity of water (mm) over time (months) in various precipitation channels in Diospyros crassiflora plantation in 2016 and 2017. Precipitation

pathways in 2016 showed that stemflow had significantly higher water quantity (1397.11mm) than the control (435.33mm) and throughfall (374.11mm) pathways which had statistically similar water quantities. Table 1 showed that no significant differences existed between the Time (T) x Precipitation (P) pathways (T x P) treatment interactions. Time (months) of rainfall in 2016 shows that August gave significantly the highest quantity (956.33mm), unlike in 2017 where July gave higher quantity (1046.00) of water. However, September, 2016 had significantly higher water quantity than March, April, May, July, October and November, 2016. However, the water quantities of September and June, 2016 were not significantly different from each other. The statistically similar water quantities of June and July, 2016 were higher ( $p \leq 0.05$ ) than the statistically similar water quantities of March, April, May, October and November, 2016 which had the least ( $p \leq 0.05$ ) values.

Precipitation pathways in 2017 showed that stemflow (1594.00mm) and throughfall (327.00mm) gave significantly the highest and least water quantities. Summary of the rain water quantities of the precipitation pathways are significantly as follows: Stemflow > Incipient precipitation > Throughfall. In terms of time (months), July significantly had higher quantities than March, April, May, June, October and November. However, July, August and September had similar ( $p \leq 0.05$ ) water values. The statistically similar water quantities of August and September, 2017 were significantly higher than those of March, May, June, October and November, 2017. However, the water quantities of August and September were not significantly different from that of April, 2017. The statistically similar water quantities of April and October, 2017 were significantly higher than those of March, May and November, 2017 which gave the least ( $p \leq 0.05$ ) rainfall quantities. No significant differences existed between the quantities of rain water of the various treatment interactions of Time (months) X Precipitation pathways in 2017.

The study revealed that rainfall started by March and ended by November in 2016 and 2017 in *Diospyros crassiflora* plantation in Umuahia. It is a natural phenomenon that rainfall which occurs in the forest or plantation drops on the soil in three dimensions. The rain that falls on forests is partitioned into incipient, throughfall, and stemflow precipitation pathways [20, 2]. The amount or quantity of incipient precipitations varies from one ecosystem to another and its nutrients deposition into the soil is highly influenced by forest or vegetation types. The amount of precipitation during onset of rain (March - May) and towards ending of rain (October-November) in both years of the study were relatively small as compared to the months of June - September in 2016 and 2017 at Okwuta- Ibaku, Umuahia. On the vegetated soil, plants and organic materials intercept and absorb precipitation and release it slowly into the ground (Table 1).

Table 2 shows the N contents ( $\text{mg l}^{-1}$ ) and the pH values of the three Precipitation pathways in two study years (2016 and 2017) at Umuahia, Nigeria. The result revealed that N contents in 2016 and 2017 were not significantly different from each other. Precipitation pathways within periods (months) show that the N contents in 2016 and 2017 were also not

significantly different from each other. Table 2 revealed that N contents of the treatment interactions of Years x Precipitation pathways were not significantly different from each other. It also revealed that no significant differences existed between the pH values of 2016 and 2017. Precipitation pathways indicate that Throughfall and Stemflow had significantly the highest and least pH-values.

Summary of the pH values of the Precipitation pathways are significantly as follows: Throughfall (pH 5.45) > Rainfall (pH 5.28) > Stemflow (pH 4.94). Treatment interactions of Years x Precipitation pathways shows that Throughfall in 2016 (pH 5.51) had significantly higher ( $p \leq 0.05$ ) pH-values than the statistically similar pH contents of Stemflow in 2016 (pH 4.94) and Stemflow in 2017 (pH 4.94).

Table 3 shows that the P contents and the Ca contents of the three precipitation pathways in 2016 and 2017 were not significantly different from each other. Precipitation pathways showed Stemflow had significantly higher P content ( $0.15 \text{ mg l}^{-1}$ ) than Throughfall and Rainfall ( $0.14 \text{ mg l}^{-1}$ ) which had statistically similar P contents. Treatment interactions of Year x Precipitation pathways, Rainfall ( $0.15 \text{ mg l}^{-1}$ ) and Stemflow ( $0.15 \text{ mg l}^{-1}$ ) in 2016 with similar ( $p \leq 0.05$ ) contents had the highest ( $p \leq 0.05$ ) P values. Stemflow in 2017 and Throughfall in 2016 had statistically similar ( $0.13 \text{ mg l}^{-1}$  each, P contents which gave the least results. Summary of the results of the P contents of the Year x Precipitation pathways are significantly as follows: Rainfall in 2016 = Stemflow in 2016 (each  $0.15 \text{ mg l}^{-1}$ ) > Rainfall in 2017 = Throughfall in 2017 = Throughfall in 2016 (each  $0.13 \text{ mg l}^{-1}$ ).

Precipitation pathways shows stemflow and rainfall had significantly the highest and least Ca contents respectively. Summary of the Ca contents of the precipitation pathways are significantly as follows: Stemflow ( $70.95 \text{ mg l}^{-1}$ ) > Throughfall ( $68.35 \text{ mg l}^{-1}$ ) > Rainfall ( $65.12 \text{ mg l}^{-1}$ ). The Ca contents of Year x Precipitation pathways treatment interactions, Stemflow in 2016 ( $71.30 \text{ mg l}^{-1}$ ) and rainfall in 2016 ( $63.89 \text{ mg l}^{-1}$ ) had significantly the highest and least Ca contents respectively. Summary of the Ca contents of the Year x Precipitation pathways treatment interactions is significantly as follows: Stemflow in 2016 ( $71.30 \text{ mg l}^{-1}$ ) > Stemflow in 2017 ( $70.59 \text{ mg l}^{-1}$ ) > Throughfall in 2016 ( $68.78 \text{ mg l}^{-1}$ ) > Throughfall in 2017 ( $67.93 \text{ mg l}^{-1}$ ) > Rainfall in 2017 ( $66.36 \text{ mg l}^{-1}$ ) > Rainfall in 2016 ( $63.89 \text{ mg l}^{-1}$ ).

Table 4 shows the K and the Na contents of three precipitation pathways in 2016 and 2017. The K contents in 2016 and 2017 were not significantly different from each other. Precipitation pathways revealed that stemflow and throughfall gave significantly the highest and least K contents respectively. Summary of the K contents of the precipitation pathways are significantly as follows: Stemflow ( $11.60 \text{ mg l}^{-1}$ ) > Rainfall ( $10.59 \text{ mg l}^{-1}$ ) > Throughfall ( $10.17 \text{ mg l}^{-1}$ ). The K contents of treatment Interactions of Year x Precipitation pathways, the statistically similar K contents of Stemflow in 2017 ( $11.64 \text{ mg l}^{-1}$ ) and in 2016 ( $11.55 \text{ mg l}^{-1}$ ) had the highest ( $p \leq 0.05$ ) K results. Throughfall in 2017 ( $9.98 \text{ mg l}^{-1}$ ) had significantly the least K value.

Summary of the K contents of the treatment interactions of Years x Precipitation pathways are stated below: Potassium contents of Stemflow in 2017 = Stemflow in 2016 > Rainfall in 2017 = Rainfall in 2016. However, Rainfall in 2017 had higher ( $p \leq 0.05$ ) K contents than Throughfall in 2016 and 2017. The K content of Throughfall in 2016 and Rainfall in 2016 were not significantly different from each other. Throughfall in 2017 had significantly the least K content.

Na contents in 2016 and 2017 were not significantly different from each other. In terms of Precipitation pathways, Throughfall ( $129.81 \text{ mg l}^{-1}$ ) followed by Stemflow ( $126.89 \text{ mg l}^{-1}$ ) had significantly the highest Na contents. Rainfall had the least ( $p \leq 0.05$ ) Na content. In terms of Year x Precipitation pathways, Throughfall in 2017 ( $130.26 \text{ mg l}^{-1}$ ) and 2016 ( $129.37 \text{ mg l}^{-1}$ ) with statistically similar Na contents gave significantly the highest Na contents. Stemflow in 2017 ( $125.63 \text{ mg l}^{-1}$ ) had the least Na content. Summary of the Na contents of the treatment interactions of Years x Precipitation pathways are significantly as follows: Throughfall in 2017 > Throughfall in 2016 > Stemflow in 2016 = Rainfall in 2017. However, the Na contents of Rainfall in 2017 = Rainfall in 2016 > Stemflow in 2017.

Table 5 shows that no significant existed between the Cl and the Fe contents of the Years of study (2016 and 2017), and also between the various Precipitation pathways. However, the table shows that significant differences existed between the treatment interactions of Years x Precipitation pathways. The statistically similar Cl contents of Stemflow in 2016, Throughfall in 2016 and Rainfall in 2017 were significantly higher than the Cl values of Rainfall in 2016, Stemflow in 2017 and Throughfall 2017. Rainfall had higher ( $p \leq 0.05$ ) Cl contents in 2017 than Rainfall in 2016. Stemflow in 2017 and Rainfall in 2017 had similar ( $p \leq 0.05$ ) Cl contents. The Cl contents of Rainfall in 2016, Throughfall in 2017 and Stemflow in 2017 were not significantly different from each other.

The precipitation pathways revealed that stemflow ( $18.62 \text{ mg l}^{-1}$ ) and throughfall ( $18.62 \text{ mg l}^{-1}$ ) had statistically similar Fe contents that were significantly higher than the Fe contents of rainfall ( $17.96 \text{ mg l}^{-1}$ ). In terms of Interaction Years x Precipitation pathways, throughfall in 2016 ( $18.99 \text{ mg l}^{-1}$ ) had significantly higher Fe content than the rainfall Fe in 2017 ( $18.73 \text{ mg l}^{-1}$ ), rainfall in 2016 ( $18.06 \text{ mg l}^{-1}$ ), through fall in 2017 ( $18.20 \text{ mg l}^{-1}$ ) and stemflow in 2017 ( $18.73 \text{ mg l}^{-1}$ ). However, the Fe contents of throughfall in 2016 ( $18.99 \text{ mg l}^{-1}$ ) was not significantly different from the Fe contents of stemflow ( $18.73 \text{ mg l}^{-1}$ ) in 2017. Although the Fe contents of rainfall in 2017 and in 2016 were statistically similar, rainfall generally had the least ( $p \leq 0.05$ ) Fe value among the precipitation pathways.

Table 6 summarized the Mg and the Pb contents of three precipitation pathways in 2016 and 2017. The Precipitation pathways show that stemflow ( $159.67 \text{ mg l}^{-1}$ ) had higher ( $p \leq 0.05$ ) Mg contents than the throughfall ( $155.06 \text{ mg l}^{-1}$ ). However, the stemflow and rainfall Mg contents were similar ( $p \leq 0.05$ ). The rainfall and throughfall Mg contents were not significantly different. In summary, the Mg contents of the Precipitation pathways are significantly as follows: Stemflow ( $159.67 \text{ mg l}^{-1}$ ) > Throughfall ( $155.06 \text{ mg l}^{-1}$ ), Stemflow =

Rainfall ( $157.96 \text{ mg l}^{-1}$ ). The Mg contents of the study years (2016 and 2017) and the Years x Precipitation pathways were not significantly different respectively. The Pb contents of the two study years, 2016 and 2017, the three precipitation pathways (Rainfall, Stemflow and Throughfall) and Interactions Years x Precipitation pathways were not significantly different from each other per treatment factor.

The results of table 2 to 6 of the study revealed that The various precipitation pathways (incipient precipitation/rainfall, throughfall and stemflow) obtained from *D. crassiflora* plantation in Umuahia contained ten mineral elements, though some of these mineral nutrients were in large quantity (sodium, calcium, magnesium and chlorine etc, while others were in very minute quantity (phosphorus, potassium, iron and lead etc). [2] reported that precipitations in the form of incipient rainfall, stemflow and throughfall contained ten (10) nutrient elements including a heavy metal at very negligible value (Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Sodium, Chlorine, Iron, Lead and pH) on *D. crassiflora* plantation. [3, 21] noted the concentration of micronutrients in the precipitation pathways of *E. cylindricumare* similar to those in tree-based land use systems and spontaneous tree vegetation of Central America where Pine and Oak precipitation pathways were enriched with copper (Cu), Iron (Fe), Manganese (Mn) and zinc (Zn).

The presence of nutrient concentrations recorded in the various precipitation pathways of *Diospyroscassiflora* could be attributed to greater rain-water-based leach ability of bark tissue in stemflow and foliar leaching of nutrients in throughfall. Nutrient concentrations on precipitation pathways between 2016 and 2017 in *D. crassiflora* plantation are closely related to the age of the plant species and weather conditions of the study site [2]. This feature could influence the seasonal changes of nutrient concentrations in litter and their potential retranslocation capacity. [22] stated that forest age has a significantly positive influence on soil respiration in *Pinustaeda* plantations. The mineral nutrients obtained through throughfall and stemflow in *Diospyros crassiflora* in 2016 and 2017 are in soluble forms [2].

This research revealed that water through precipitation pathways and nutrient concentrations in the following order to the forest floor/soil: stemflow>throughfall>incipient precipitation. As the tree canopy partitions rainfall into stemflow, the intercepted water washes off nutrients that were deposited in the canopy by dry atmospheric deposition or animal droppings. Stemflow element concentrations were generally much greater than those of throughfall, and the nutrient concentration of both stemflow and throughfall were related to the seasonal presence or absence of *Diospyroscassiflora* foliage in the year 2016 and 2017. Although decomposition of leaf litter supplies very large amounts of mineral nutrients to the forest floor, such nutrients are released slowly by decomposition of organic matter. However, nearly all throughfall and stemflow nutrients are in solution and are immediately available for absorption by roots [20]

**Table 1.**Quantity of Water (mm) Overtime (months) of Various Precipitation Pathways in D. crassiflora Plantation Umuahia, Nigeria in 2016 and 2017

Time (Months)	Quantity of water (mm)							
	2016				2017			
	Precipitation pathways				Precipitation pathways			
	Incipient prec.(control)	Stemflow	Throughfall	Mean (Months)	Incipient prec.(control)	Stemflow	Throughfall	Mean (Months)
March	268.00	949.00	296.00	504.33	102.00	1382.00	99.00	528.00
April	273.00	1134.00	239.00	548.67	408.00	1796.00	384.00	862.00
May	366.00	1159.00	342.00	622.33	240.00	1287.00	175.00	567.00
June	535.00	1580.00	417.00	844.00	369.00	1497.00	312.00	726.00
July	535.00	1461.00	387.00	794.33	762.00	1710.00	666.00	1046.00
August	796.00	1827.00	474.00	956.33	577.00	1796.00	412.00	928.00
September	602.00	1793.00	474.00	956.33	706.00	1851.00	384.00	980.00
October	301.00	1353.00	249.00	634.33	385.00	1722.00	247.00	785.00
November	242.00	1318.00	259.00	606.33	347.00	1307.00	267.00	640.00
Mean (Prec. Pathways)	435.33	1397.11	374.11		433.00	1594.00	327.00	
F-LSD (0.05)								
	2016				2017			
Time (months) (T)	131.50				123.50			
Precipitation pathways (P)	117.00				78.80			

**Table 2.**Nitrogen ( $\text{mg l}^{-1}$ ) Contents and pH Values of Three Precipitation Pathways in 2016 and 2017 at Diospyros crassiflora Plantation

N content ( $\text{mg l}^{-1}$ )					pH values			
Precipitation pathways					Precipitation pathways			
Year	Rainfall	Stemflow	Throughfall	Mean (Year)	Rainfall	Stemflow	Throughfall	Mean (Year)
2016	14.19	14.77	15.19	14.71	5.23	4.94	5.51	5.23
2017	14.04	13.93	17.07	15.02	5.33	4.94	5.40	5.22
Mean (P)	14.11	14.35	16.13		5.28	4.94	5.45	
F-LSD (0.05) for N					F - LSD (0.05) for $\text{P}^{\text{H}}$ value			
Year (Y)					NS			
Prec. Pathways (P)					NS			
Y x P					NS			

**Table 3.** Phosphorus (P) and Calcium (Ca) contents (mg l<sup>-1</sup>) Contents of Three Precipitation Pathways in 2016 and 2017at Diospyros crassiflora Plantation

P content (mg l <sup>-1</sup> )					Ca content (mg l <sup>-1</sup> )			
Precipitation pathways					Precipitation pathways			
Year	Rainfall	Stemflow	Throughfall	Mean(Year)	Rainfall	Stemflow	Throughfall	Mean(Year)
2016	0.15	0.15	0.13	0.14	63.89	71.30	68.78	67.99
2017	0.14	0.13	0.14	0.14	66.36	70.59	67.93	68.29
Mean (P)	0.14	0.15	0.14		65.12	70.95	68.35	
F-LSD <sub>(0.05)</sub> for P					F – LSD <sub>(0.05)</sub> for Ca			
Year (Y)				NS	NS			
Prec. Pathways (P)				0.01	0.24			
Y x P				0.01	0.55			

**Table 4.** Potassium (K) and Sodium (Na) Contents (mg l<sup>-1</sup>) of Three Precipitation Pathways in 2016 and 2017at Diospyros crassiflora Plantation

K content (mg l <sup>-1</sup> )					Na content (mg l <sup>-1</sup> )			
Precipitation pathways					Precipitation pathways			
Year	Rainfall	Stemflow	Throughfall	Mean(Year)	Rainfall	Stemflow	Throughfall	Mean(Year)
2016	10.53	11.55	10.35	10.81	126.89	128.15	129.37	128.14
2017	10.64	11.64	9.98	10.75	127.74	125.63	130.26	127.88
Mean (P)	10.50	11.60	10.17		122.31	126.89	129.81	
F-LSD <sub>(0.05)</sub> for K					F – LSD <sub>(0.05)</sub> for Na			
Year (Y)				NS	NS			
Prec. Pathways (P)				0.16	0.58			
Y x P				0.21	0.90			

**Table 5.** Chlorine (Cl) and Iron (Fe) Contents ( $\text{mg l}^{-1}$ ) of Three Precipitation Pathways in 2016 and 2017 at Diospyros crassiflora Plantation

Cl content ( $\text{mg l}^{-1}$ )					Fe content ( $\text{mg l}^{-1}$ )			
Precipitation pathways					Precipitation pathways			
Year	Rainfall	Stemflow	Throughfall	Mean(Year)	Rainfall	Stemflow	Throughfall	Mean(Year)
	l	w	l	)	l	w	l	)
2016	256.00	262.30	261.48	259.93	18.06	18.51	18.99	18.52
2017	259.78	257.89	258.22	258.63	17.86	18.73	18.20	18.26
Mean (P)	257.89	260.09	259.85		17.96	18.62	18.59	
F-LSD <sub>(0.05)</sub> for Cl					F - LSD <sub>(0.05)</sub> for Fe			
Year (Y)					NS			
Prec. Pathways (P)					NS			
Y x P					2.53			
					0.22			
					0.29			

**Table 6.** Magnesium (Mg) and Lead (Pb) Contents ( $\text{mg l}^{-1}$ ) of three Precipitation Pathways in 2016 and 2017 at Diospyros crassiflora plantation

Magnesium content ( $\text{mg l}^{-1}$ )					Lead content ( $\text{mg l}^{-1}$ )			
Precipitation pathways					Precipitation pathways			
Year	Rainfall	Stemflow	Throughfall	Mean(Year)	Rainfall	Stemflow	Throughfall	Mean(Year)
	l	w	l	)	l	w	l	)
2016	159.33	162.15	153.93	158.47	0.01	0.02	0.01	0.01
2017	156.59	157.22	156.19	156.67	0.01	0.02	0.01	0.01
Mean (P)	157.96	159.69	155.06		0.01	0.02	0.01	
F-LSD <sub>(0.05)</sub> for Mg					F - LSD <sub>(0.05)</sub> for Pb			
Year (Y)					NS			
Prec. Pathways (P)					3.42			
Y x P					NS			
					NS			

## Conclusion

Variation in the quantity of rainfall from different precipitation pathways/channels affected mineral element concentrations (Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Sodium, Chlorine, Iron, Lead and pH) in Diospyros crassiflora plantation. Mineral nutrients delivery to the forest floor/soil through precipitation pathways: incipient precipitation, throughfall and stemflow were similar at the Diospyros crassiflora plantation in 2016 and 2017, although there was considerable inter-annual variation in distribution among throughfall, stemflow and retention by the canopy within the study months. The study further revealed that irrespective of the month which precipitation

pathways occurred, it always associated with nutrients, though concentrations of these mineral nutrients depend on intensity of rainfall and leachability of plant either via throughfall or stemflow pathways.

#### Author Address:

<sup>1</sup> Department of Forestry and Wildlife Resources Management, University of Calabar Calabar, Nigeria

<sup>2</sup> Forestry Research Institute of Nigeria, P.M.B.5054 Ibadan, Oyo State, Nigeria

#### References

1. Pidwirny M.,2006. "Fundamentals of Physical Geography", 2<sup>nd</sup> edition, [www.Physicalgeography.net](http://www.Physicalgeography.net).
2. Nsien I. B.,2020. "Leaf litter oroduction and nutrient cycling rates, growth and yield parameters of Maize (*Zea mays* L.) in *Diospyros crassiflora* (Hiern–FWTA) Plantation in Okwuta-Ibeku, Umuahia, Abia State, Nigeria", Dissertation submitted to the post graduate school, Michael Okpara University of Agriculture, Umudike, Abia State, in partial fulfilment of the requirements for the award of Degree of Doctor of Philosophy in the Department of Forestry and Environmental Management.
3. Koyejo A. O., Okpara I. G., Adetunji, A. S., 2020. "Precipitation pathways a channel of nutrient cycling in an *Entandrophragmacylindricum*(Sprague) plantation in Onne, Rivers State, Nigeria", *Journal of Research in Forestry, Wildlife & Environment*, 12(2):212-224.
4. Su L., Xie Z., Xu W., Zhao C., 2019. "Variability of throughfall quantity in a mixed evergreen-deciduous broadleaved forest in central China", *Journal of Hydrology and Hydromechanics*,67:225-231.
5. Sheng H., Cai T., 2019. "Influence of rainfall on canopy interception in mixed broadleaved - Korean Pine Forest in Xiaoxing an Mountains, Northeastern China", *Forests*,10 (3):248.
6. Chrisphine, O. M., Odhiambo, A. M., & Boitt, K. M. 2016. Assessment of Hydrological Impacts of Mau Forest, Kenya. *Hydrology Current Research*, 7, Article 1000223.
7. El-Zeiny, A., & El-Kafrawy, S. 2017. Assessment of Water Pollution Induced by Human Activities in Burullus Lake Using Landsat 8 Operational Land Imager and GIS. *The Egyptian Journal of Remote Sensing and Space Science*, 20, S49-S56.
8. Igu, N.I. and Marchant, R. 2017. Potential and Determinants of Carbon Storage of Freshwater Swamp Forests in the Niger Delta. *Open Journal of Ecology*, 7, 199-210
9. Igu, N.I. and Marchant, R. 2016. Aboveground Carbon Storage in a Freshwater Swamp Forest Ecosystem in the Niger Delta. *Carbon Management*, 7, 137-148.

10. Martiniello, P. and Teixeira da Silva, J. 2011. Physiological and bioagronomical aspect involved in growth and yield components of cultivated forage species in Mediterranean environments. *European Journal of Plant Science and Biotechnology*, 5, 64-98.
11. Alika J. E., 2006. "Statistical and Research Methods", 2<sup>nd</sup> Edition, Ambik Press, Benin City, Nigeria, pp. 366.
12. Kiliç, Z.2021. Water Pollution: Causes, Negative Effects and Prevention Methods. *İstanbul Sabahattin Zaim Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 3, 129-132.
13. Mustafa, M. T., Hassoon, K. I., Hussain, H. M., & Abd, M. H. 2017. Using Water Indices (NDWI, MNDWI, NDMI, WRI and AWEI) to Detect Physical and Chemical Parameters by Apply Remote Sensing and GIS Techniques. *International Journal of Research-Granthaalayah*, 5, 117-128.
14. Berghöfer, A., Stadler, C. and Langdale, G. 2013. Sustaining Life: The Cloud Forests of Kafa. Marketing Concept for the Kafa Biosphere Reserve, Ethiopia. Report to NABU—The Nature and Biodiversity Conservation Union Germany, Berlin.
15. Kim, R.Y., Yoon, J.K., Kim, T.S., Yang, J.E., Owens, G. and Kim, K.R.2015.
16. Bioavailability of Heavy Metals in Soils: Definitions and Practical Implementation—A Critical Review. *Environmental Geochemistry and Health*, 37, 1041-1061
17. Warra, H.H., Mohammed, A.A. and Melanie, D.N. 2015. Impact of Land Cover Changes and Topography on Soil Quality in the Kasso-Catchment, Bale Mountains of Southeastern Ethiopia.
18. Rama Rao, S., Raju, M., Pnad, A. and Krisna Murth, O. 2014. Effect of Supplementing Microbial Phytase in Diets Containing Graded Concentrations of Calcium on Performance, Shell Quality and Bone Mineral Parameters in Layers. *Animal Feed Science and Technology*, 193, 102-110.
19. Adilakshmi, A., & Venkatesan, V. 2024. Effective Monitoring of Noyyal River Surface Water Quality Using Remote Sensing and Machine Learning and GIS Techniques. *Desalination and Water Treatment*, 320, Article 100630.
20. Pallardy S. G., 2008. "Mineral Nutrition, Learn more about Throughfall and Stemflow. In: *Physiology of Woody Plants*", (Third Edition).
21. Cantu S. I., Gonzalez R. H., 2001. "Interception loss, throughfall and stemflow chemistry in pine and oak forests in northeastern Mexico", *Tree Physiology*.21:1009-1013.
22. Wiseman P. E., Seiler J. R., 2004. "Soil CO<sub>2</sub> efflux across for four age classes of plantation loblolly pine (*Pinustaeda* L.) On the Virginia Piedmont". Miscellaneous publication, *Forest Ecology and Management*, 192:297-31.