ECOLOGICAL AND SYNERGISTIC EVALUATION OF THE NUTRIENT DYNAMICS OF THE PRECIPITATION FLUX IN A GUINEA SAVANNA, NORTH-CENTRAL NIGERIA

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Abstract

Tropical savannas are widespread, rich in biodiversity, with nutrient cycling being central to long-term sustainability of its phytodiversity. Understory precipitation (canopyfall and stemflow) and freefall from 13 rainfall episodes were sampled in isolated, naturally growing tree stands of Azadirachta indica (A. Juss), Daniella oliveri (Rolfe) Hutch. & Dalziel, Parkia biglobosa (Jacq.) Benth, Prosopis africana (Guill. & Perr.) and Vitellaria paradoxa (Gaertner) F. Calcium and magnesium were spectrophotometrically analysed, potassium determined with flame photometry, while nitrate-nitrogen and phosphatewas phosphorus were determined via colorimetric titration. Results showed that understory precipitation fluxes (canopyfall and stemflow) were predominantly richer in nutrient return than the freefall, just as the stemflow was the more nutrient-rich understory precipitation. Pearson's correlation reflected dominant synergistic patterns between canopyfall and stemflow, especially for cationic elemental nutrients. It is indicative that extended incanopy precipitation residence time, as well as branch and bark tissue leaching-derived base content, are synchronizing factors involved in the nutrient enrichment nature of canopyfall and stemflow, in terrestrial ecosystems. This study points out the agroecological, ecophysiological, and biogeochemical cycling potentials of tropical tree cover, understory precipitation flux, and their rapid nutrient supply to tropical ecosystem soils.

Key Words: Canopyfall, freefall, Guinea savanna, Nutrient dynamics, Precipitation, Stemflow

Introduction

Nutrient cycling provides an insight into the management of vegetation growing on low fertility tropical soils (Congdon and Herborn, 1993). It is a key ecological process which interchanges elements through the biotic and geochemical aspects of the ecosystem. Nutrient cycling essentially involves the processes of uptake and storage of nutrients in flora tissues and litter decomposition, as well as transformation of nutrients by the flora and fauna of the soil (Foster and Bhatti, 2006). Ecosystem stability and optimum functioning is propelled by nutrient rate turnover (Brasell *et al.*, 1980). Nutrient cycles are linked to the hydrological cycle due to the

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fact that water represents the main solvent and transport mechanism of nutrient elements from tree stands to the soil (Bruijnzeel, 2001; Chuyong *et al.*, 2004). According to Newson (1997), nutrient wash-off from the leaf and stem of plants represents a key vehicle in the nutrient return process. The accumulation of dust particles on the leaves and branches of trees which is transported to the soil via the fluxes of throughfall and stemflow is a potential source of mineral nutrient and nitrogen input (Muoghalu *et al.*, 2000).

Ecosystem nutrient budgets have been developed around the dynamics of additions, losses and fluxes as an oversight target towards nutrient supply sustainability (Laclau et al., 2003). The significant interaction of tropical vegetation with rainfall is recognized on physiological and eco-hydrological bases (Marin-Tobin et al., 2000; Iida et al., 2005). When rain falls on tree canopies, a proportion reaches the soil as throughfall and stemflow, the rest is retained in the canopy and subsequently evaporated, water and nutrients are channelled into zones around tree trunks (Johnson and Lehmann, 2006). Furthermore, water fluxes are partitioned into distinct pathways by the canopy and root tropical segments of trees; thus. influencing chemical constitution as well as concentration (Bundt et al., 2001).

Canopyfall describes the process of precipitation running through plant canopy and is influenced by factors such as density of leaf and stem, intensity, and duration of precipitation. It is also notable that precipitation quantity which passes through canopies varies significantly based on vegetation forms (Pidwirny, 2006).

Stemflow is the partial gross rainfall, flowing down along the stems and tree trunks and reaching the soil. As an ecosystem nutrient flux, stemflow gets into the soil around the tree base and in effect enables drought-resistant mechanisms in trees (Martinez-Meza and Whitford, 1996; Levia and Germer, 2015; Van Stan and Gordon, 2018). Vegetation often modifies the intensity and distribution of precipitation falling on and through the leaf and trunk. According to Pidwirny (2006), vegetation is capable of intercepting about 50% of rainfall through the leaf. In deciduous trees, the leaves generally intercept about 20%-30% of rainwater. During a precipitation episode, canopy nutrients are leached due to the nutrient concentration differential between the tree and rainwater (Kopacek et al., 2009; Poleto et al., 2021).

Ecosystem research focus has been directed towards net primary production (NPP) evaluation. which implies quantity of carbon fixed into organic matter. Nevertheless, nutrient wash from leaves and stem during rain episodes is a component source of nutrient return from trees to soil (Nye, 1960; Newson, 1997; Ward, 2000). Flux element estimation from incident rainfall, throughfall and stemflow has continued to constitute a familiar approach in nutrient budgetary analysis overtime (Likens et al., 1977), with epiphytic plants and lichens also contributing roles in nutrient uptake from intercepted precipitation (Houle et al., 1999: Mendieta-Leiva et al., 2020).

Savanna biomes are very extensive in the Americas, Africa and India (Scholes and Hall, 1996), with the interaction between nutrient availability and water being a key correlational driver of savanna ecosystems (Reatto *et al.*, 1998; Bustamante et al., 2006). Deep-rooted trees exert significant effects on ecosystem productivity through nutrient cycling (Chang and Matzner, 2000; Anka and Sanda, 2020), because they explore soil pools that are ordinarily inaccessible to shallow-rooted species. The tree stands from the five tree species in this study (Azadirachta indica, Daniella oliveri, Parkia biglobosa, Prosopis africana and Vitellaria paradoxa) have notably coarse, rough-patterned bark surfaces, which are potential factors for stemflow enhanced precipitation, enabling water to run or trickle along the bark in more distinct channels. It is with the foregoing that this study was aimed at determining cationic and anionic nutrient returns, from the understory precipitation fluxes of the indicator tree species, as well as the co-relationship of precipitation fluxes in the ecosystem.

Methodology

Study Area

The study was conducted in University of Ilorin campus (8.4912°N, 4.5950°E) Ilorin, in the Guinea Savanna belt of Nigeria (Oyedeji et al., 2021) (Figure 1). The study area is an undisturbed woodland/grassland characterized by rainy (April October) and dry (November -March) seasons (Ovedeji et al., 2014), with rainfall annual of 1.200mm

(Olaniran. 2002). 75-80% relative humidity, and an average annual temperature of 33°C-34°C (Ajadi et al., 2011). The natural vegetation is dominated by grass cover, with significant tree cover composition dominated by deciduous tree species such as A. indica, D. oliveri, P. biglobosa, P. africana and V. paradoxa, in sparsely distributed pattern (Oyedeji et al., 2014). Other relatively common species include Terminalia catappa, Delonix regia, Gmelina arborea and Mangifera indica (Babalola and Raji, 2016; Oyedeji et al., 2021). The study area also has expansive vicinity areas characterized by Tectona grandis and Jatropha curcas plantations. Sparse distribution of rocky outcrops is also evident around the study area.

Experimental Design

Ten isolated tree stands (two stands per species) were used in sampling canopyfall into sterile, funnelled containers, while the stemflow was sampled via sterile channelled into funnelled tubes containers. 13 rainfall episodes were sampled in this study across the rainy months of May to July. Furthermore, a control precipitation group (freefall) was also sampled in triplicate per rainfall episode. The experiment was designed on the fundamental basis of tree stand isolation, thereby ensuring homogeneity of precipitation samples obtained from each tree stand.



Ecological and Synergistic Evaluation of the Nutrient Dynamics......Oyeyinka et al.

Fig. 1: Map of the sampling points within the Study Area

Precipitation Sample Collection

Canopyfall precipitation samples were collected in the study site with two funnelled, plastic collectors on the ground, beneath each tree canopy. Stemflow samples were collected through the interception of rainwater running along each tree trunk near the ground, via a mounted sterile, flexible interception tube, channelled into a clean two-litre plastic container. Freefall (open rain) samples were collected in open space from direct rainfall with three funneled plastic collectors. Precipitation samples were collected after each of the 13 rainfall episodes into labelled sampling bottles, and stored in cold condition (4°C), for laboratory analysis.

Digestion and Laboratory Analysis

Nitric-Perchloric acid (HNO₃-HClO4) digestion method was used as described by AOAC (1990). 5 mL of each water sample (canopyfall, stemflow and freefall) was added into a conical flask. 10 mL of trioxonitrate V acid (HNO3) was then added carefully, after which 7.5 mL of conc. perchloric acid (HClO4) was added. The mixture was then filtered with a Whatman Filter Paper No. 42 (125 mm). A clear solution (digestate) was obtained and collected into 60 mL bottles for analysis. Elemental nutrient analysis for calcium and magnesium was spectrophotometrically determined using Atomic Absorption the Spectrophotometer (210 VPG, Bulk Scientific Inc., Norwalk, U.S.A), while potassium was analysed with the Flame Photometer (PFP 7, JENWAY, United Kingdom). Nitrate-nitrogen and phosphate-phosphorus were quantitatively determined using colorimetric titration.

Data Analysis

Data obtained were subjected to oneway Analysis of Variance and Fischer's significant difference least mean separation using the MINITAB statistical software. Statistical tests were carried out at 0.05 confidence level. Understory precipitation flux (canopyfall and stemflow) and freefall data for each nutrient, was subjected to the Pearson's correlational (r) analysis at $p \le 0.05$.

Results

Rainfall was observed across the months May to July, from which precipitation samples were collected. Calcium concentrations in the canopyfall of *A. indica* (1.96 \pm 0.55 mg/L), *P. biglobosa* (1.79 \pm 0.71 mg/L), *P. africana* (1.88 \pm 0.58 mg/L) and *V. paradoxa* (2.24 \pm 0.92 mg/L) were higher than that of the freefall (1.74 \pm 0.39 mg/L). Moreover, the stemflow had higher calcium concentration than canopyfall in three (*D. oliveri*, *P. biglobosa* and *V. paradoxa*) of the five tree species (Figure 2 to 6).

Potassium concentration in the canopyfall of *A. indica* $(2.08 \pm 1.60 \text{ mg/L})$, *D. oliveri* $(1.73 \pm 1.75 \text{ mg/L})$, *P. biglobosa* $(1.92 \pm 1.41 \text{ mg/L})$ and stemflow of all the five tree species were higher that of the freefall $(1.71 \pm 1.66 \text{ mg/L})$. Notably, stemflow had higher potassium concentration than canopyfall across all five tree species (*A. indica*, *D. oliveri*, *P. biglobosa*, *P. africana* and *V. paradoxa*) (Figure 2 to 6).

Magnesium concentration in the canopyfall of A. indica (1.22 ± 0.89) mg/L), *P. africana* (1.21 ± 0.92 mg/L), *V.* paradoxa $(1.29 \pm 0.93 \text{ mg/L})$ and stemflow of D. oliveri (1.43 ± 0.99) mg/L), *P. biglobosa* (1.21 ± 0.91 mg/L), P. africana $(1.37 \pm 1.03 \text{ mg/L})$, and V. *paradoxa* $(1.35 \pm 1.07 \text{ mg/L})$ were higher than the magnesium concentration in the freefall (1.18)± 0.90 mg/mL). Furthermore. stemflow had higher magnesium concentration than canopyfall in four of the five tree species, except A. indica (Figure 2 to 6).

Nitrate-nitrogen concentration in the canopyfall and stemflow across all the five tree species $(0.44 \pm 0.24 \text{ mg/L to } 1.57 \pm 0.76 \text{ mg/L})$ were higher than that of the freefall $(0.23 \pm 0.17 \text{ mg/L})$. Likewise, canopyfall had higher nitrate-nitrogen concentration than stemflow in three (*P. biglobosa, P. africana* and *V. paradoxa*) of the five species (Figure 2 to 6).

Phosphate-phosphorus concentration in the canopyfall of all five tree species (0.02 ± 0.01 mg/L to 0.02 ± 0.02 mg/L) and the stemflow of A. indica $(0.02 \pm 0.01 \text{ mg/L})$, D. oliveri $(0.06 \pm 0.04 \text{ mg/L})$, P. biglobosa $(0.02 \pm 0.02 \text{ mg/L}), P. africana (0.04 \pm$ 0.03 mg/L) were higher than the concentration in the freefall (0.01 ± 0.01) mg/L), while V. paradoxa stemflow contained comparable phosphatephosphorus concentrations with the freefall $(0.01 \pm 0.01 \text{ mg/L})$ (Figure 2 to 6). **Correlational Analysis of Understory Precipitation fluxes (Canopyfall &** Stemflow), and Freefall

Pearson's correlation (r) showed that for calcium nutrient, the understory precipitation fluxes (canopyfall and stemflow) had consistent inverse relationship with freefall in four tree species (Table 1). In *A. indica* however, canopyfall and stemflow showed negative to weak positive correlation respectively, with freefall. Notably, between canopyfall and stemflow there was moderate positive (*A. indica*), significant moderate positive (*D. oliveri*), and significant strong positive correlations (*P. biglobosa*, *P. africana* and *V. paradoxa*) respectively (Table 1).

For potassium nutrient, canopyfall and stemflow had significant strong positive correlation with freefall in four of the five tree species, with the exception of the stemflow of *A. indica* with a weak positive correlation with freefall (Table 2). Equally, canopyfall had significant strong correlation with stemflow in four of five tree species, except the moderate positive correlation in *A. indica* (Table 2). For magnesium nutrient, canopyfall and stemflow had significantly strong correlations with freefall in all the five tree species (Table 3). Similarly, within the understory precipitation fluxes, there was significantly positive correlation, across all five tree species (Table 3).

For the anionic nutrients nitratenitrogen and phosphate-phosphorus, diverse and multidirectional correlational patterns were generally observed between the canopyfall, stemflow and freefall, ranging from the predominant weak positive correlation to negative and moderate positive correlations (Table 4 and 5).







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Fig. 3: Nutrient dynamics of understory precipitation (canopyfall, stemflow) samples of *D. oliveri*, and Freefall



Ecological and Synergistic Evaluation of the Nutrient Dynamics......**Oyeyinka et al.**

Fig. 4: Nutrient dynamics of understory precipitation (canopyfall, stemflow) samples of *P. biglobosa*, and freefall



Fig. 5: Nutrient dynamics of understory precipitation (canopyfall, stemflow) samples of *P. africana*, and freefall



Fig. 6: Nutrient dynamics of understory precipitation (canopyfall, stemflow) samples of *V. paradoxa*, and freefall

| •••••• | | | | | | | | | | | |
|------------|---------|-------------|--------------|--------------|--------------|---------|--------------|--------------|---------|--------|--|
| | C1 | C2 | C3 | C4 | C5 | S1 | S2 | S 3 | S4 | S5 | |
| C2 | 0.914** | | | | | | | | | | |
| C3 | 0.714** | 0.479 | | | | | | | | | |
| C4 | 0.956** | 0.851** | 0.775** | | | | | | | | |
| C5 | 0.942** | 0.827** | 0.748^{**} | 0.988^{**} | | | | | | | |
| S 1 | 0.507 | 0.391 | 0.534 | 0.458 | 0.355 | | | | | | |
| S2 | 0.793** | 0.623* | 0.784^{**} | 0.850^{**} | 0.867^{**} | 0.267 | | | | | |
| S 3 | 0.681** | 0.478 | 0.747^{**} | 0.811^{**} | 0.825^{**} | 0.200 | 0.893** | | | | |
| S4 | 0.930** | 0.813** | 0.771** | 0.948^{**} | 0.907^{**} | 0.696** | 0.752** | 0.706^{**} | | | |
| S5 | 0.831** | 0.657^{*} | 0.878^{**} | 0.862^{**} | 0.808^{**} | 0.761** | 0.808^{**} | 0.714^{**} | 0.932** | | |
| FF | -0.217 | -0.205 | -0.251 | -0.238 | -0.292 | 0.004 | -0.099 | -0.035 | -0.199 | -0.126 | |

Table 1: Pearson's correlational analysis (r) between understory precipitation flux (Canopyfall & Stemflow), and Freefall for calcium nutrient

**Correlation is significant at ≤ 0.01 ; *correlation is significant at ≤ 0.05 . C1= Canopyfall (*A. indica*); C2= Canopyfall (*D. oliveri*); C3= Canopyfall (*P. biglobosa*); C4= Canopyfall (*P. africana*); C5= Canopyfall (*V. paradoxa*); S1= Stemflow (*A. indica*); S2= Stemflow (*D. oliveri*); S3= Stemflow (*P. biglobosa*); S4=Stemflow (*P. africana*); S5= Stemflow (*V. paradoxa*); FF= Freefall

Table 2: Pearson's correlational analysis (r) between understory precipitation flux (Canopyfall & Stemflow), and Freefall for potassium nutrient

| Polassia | | | | | | | | | | | |
|------------|--------------|--------------|--------------|--------------|--------------|---------|--------------|--------------|--------------|---------|--|
| | C1 | C2 | C3 | C4 | C5 | S1 | S2 | S3 | S4 | S5 | |
| C2 | 0.914** | | | | | | | | | | |
| C3 | 0.714^{**} | 0.479 | | | | | | | | | |
| C4 | 0.956** | 0.851** | 0.775** | | | | | | | | |
| C5 | 0.942^{**} | 0.827^{**} | 0.748^{**} | 0.988^{**} | | | | | | | |
| S 1 | 0.507 | 0.391 | 0.534 | 0.458 | 0.355 | | | | | | |
| S2 | 0.793** | 0.623* | 0.784^{**} | 0.850^{**} | 0.867^{**} | 0.267 | | | | | |
| S 3 | 0.681** | 0.478 | 0.747** | 0.811** | 0.825** | 0.200 | 0.893** | | | | |
| S4 | 0.930** | 0.813** | 0.771** | 0.948^{**} | 0.907^{**} | 0.696** | 0.752** | 0.706^{**} | | | |
| S5 | 0.831** | 0.657^{*} | 0.878^{**} | 0.862** | 0.808^{**} | 0.761** | 0.808^{**} | 0.714^{**} | 0.932** | | |
| FF | 0.773** | 0.608^{*} | 0.766** | 0.851** | 0.854** | 0.313 | 0.979^{**} | 0.868^{**} | 0.768^{**} | 0.826** | |

**Correlation is significant at ≤ 0.01 ; *correlation is significant at ≤ 0.05 . C1= Canopyfall (*A. indica*); C2= Canopyfall (*D. oliveri*); C3= Canopyfall (*P. biglobosa*); C4= Canopyfall (*P. africana*); C5= Canopyfall (*V. paradoxa*); S1= Stemflow (*A. indica*); S2= Stemflow (*D. oliveri*); S3= Stemflow (*P. biglobosa*); S4= Stemflow (*P. africana*); S5= Stemflow (*V. paradoxa*); FF=Freefall

| | C1 | C2 | C3 | C4 | C5 | S1 | S2 | S3 | S4 | S5 | |
|------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--|
| C2 | 0.867** | | | | | | | | | | |
| C3 | 0.941** | 0.773^{**} | | | | | | | | | |
| C4 | 0.989^{**} | 0.861** | 0.905^{**} | | | | | | | | |
| C5 | 0.993** | 0.867^{**} | 0.917^{**} | 0.994^{**} | | | | | | | |
| S 1 | 0.803** | 0.623^{*} | 0.843^{**} | 0.756** | 0.779^{**} | | | | | | |
| S2 | 0.991** | 0.876^{**} | 0.945^{**} | 0.985^{**} | 0.984^{**} | 0.783^{**} | | | | | |
| S 3 | 0.977^{**} | 0.821^{**} | 0.976^{**} | 0.965** | 0.963** | 0.813** | 0.986^{**} | | | | |
| S4 | 0.992^{**} | 0.870^{**} | 0.926^{**} | 0.985^{**} | 0.990^{**} | 0.815^{**} | 0.987^{**} | 0.966** | | | |
| S5 | 0.951** | 0.818^{**} | 0.987^{**} | 0.912** | 0.924^{**} | 0.876^{**} | 0.949^{**} | 0.971^{**} | 0.943** | | |
| FF | 0.739** | 0.724^{**} | 0.719** | 0.785^{**} | 0.778^{**} | 0.627^{*} | 0.779^{**} | 0.765^{**} | 0.763^{**} | 0.687^{**} | |

Table 3: Pearson's correlational analysis (r) between understory precipitation flux (Canopyfall & Stemflow), and Freefall for magnesium nutrient

**Correlation is significant at ≤ 0.01 ; *correlation is significant at ≤ 0.05 . C1= Canopyfall (*A. indica*); C2=Canopyfall (*D. oliveri*); C3= Canopyfall (*P. biglobosa*); C4= Canopyfall (*P. africana*); C5= Canopyfall (*V. paradoxa*); S1= Stemflow (*A. indica*); S2= Stemflow (*D. oliveri*); S3= Stemflow (*P. biglobosa*); S4=Stemflow (*P. africana*); S5= Stemflow (*V. paradoxa*); FF= Freefall.

Table 4: Pearson's correlational analysis (r) between understory precipitation flux (Canopyfall & Stemflow), and Freefall for nitrate-nitrogen nutrient

| | 0 | | | | | | | | | |
|------------|--------------|--------|---------|-------------|--------------|------------|-------|------------|-------|-------|
| | C1 | C2 | C3 | C4 | C5 | S 1 | S2 | S 3 | S4 | S5 |
| C2 | 0.448 | | | | | | | | | |
| C3 | 0.608^{*} | 0.169 | | | | | | | | |
| C4 | 0.804^{**} | 0.412 | 0.390 | | | | | | | |
| C5 | 0.145 | 0.187 | 0.533 | -0.128 | | | | | | |
| S 1 | 0.063 | -0.247 | 0.389 | 0.154 | 0.114 | | | | | |
| S2 | 0.030 | 0.352 | 0.392 | -0.094 | 0.787^{**} | -0.040 | | | | |
| S 3 | 0.472 | 0.455 | 0.723** | 0.585^{*} | 0.360 | 0.256 | 0.477 | | | |
| S4 | 0.533 | 0.195 | 0.551 | 0.327 | 0.200 | 0.030 | 0.377 | 0.478 | | |
| S5 | 0.560^{*} | 0.439 | 0.136 | 0.559* | -0.058 | 0.011 | 0.062 | 0.276 | 0.458 | |
| FF | 0.326 | 0.415 | 0.019 | 0.315 | 0.269 | -0.257 | 0.402 | 0.214 | 0.204 | 0.300 |

**Correlation is significant at ≤ 0.01 ; *correlation is significant at ≤ 0.05 . C1= Canopyfall (*A. indica*); C2=Canopyfall (*D. oliveri*); C3= Canopyfall (*P. biglobosa*); C4= Canopyfall (*P. africana*); C5= Canopyfall (*V. paradoxa*); S1= Stemflow (*A. indica*); S2= Stemflow (*D. oliveri*); S3= Stemflow (*P. biglobosa*); S4=Stemflow (*P. africana*); S5= Stemflow (*V. paradoxa*); FF= Freefall.

| phosphaw | nosphate-phospholas national | | | | | | | | | | |
|------------|------------------------------|---------|--------|-------------|-------------|------------|-------------|-------------|-------------|--------|--|
| | C1 | C2 | C3 | C4 | C5 | S 1 | S2 | S3 | S4 | S5 | |
| C2 | 0.071 | | | | | | | | | | |
| C3 | 0.806^{**} | 0.155 | | | | | | | | | |
| C4 | 0.007 | -0.306 | -0.010 | | | | | | | | |
| C5 | 0.016 | -0.068 | 0.067 | 0.578^{*} | | | | | | | |
| S1 | 0.373 | 0.099 | 0.194 | -0.099 | -0.108 | | | | | | |
| S2 | 0.259 | 0.157 | 0.045 | 0.138 | 0.323 | 0.329 | | | | | |
| S 3 | 0.055 | 0.137 | 0.110 | 0.439 | 0.649^{*} | -0.078 | 0.510 | | | | |
| S4 | -0.166 | 0.436 | -0.192 | 0.433 | 0.524 | 0.304 | 0.588^{*} | 0.567^{*} | | | |
| S5 | -0.101 | -0.312 | 0.184 | 0.373 | 0.098 | -0.242 | -0.334 | -0.417 | -0.183 | | |
| FF | 0.023 | 0.721** | -0.102 | -0.041 | 0.026 | 0.122 | 0.426 | 0.139 | 0.598^{*} | -0.294 | |

Table 5: Pearson's correlational analysis (r) between understory precipitation flux (Canopyfall & Stemflow), and Freefall for phosphate-phosphorus nutrient

**Correlation is significant at ≤ 0.01 ; *correlation is significant at ≤ 0.05 . C1= Canopyfall (*A. indica*); C2=Canopyfall (*D. oliveri*); C3= Canopyfall (*P. biglobosa*); C4= Canopyfall (*P. africana*); C5= Canopyfall (*V. paradoxa*); S1= Stemflow (*A. indica*); S2= Stemflow (*D. oliveri*); S3= Stemflow (*P. biglobosa*); S4=Stemflow (*P. africana*); S5= Stemflow (*V. paradoxa*); FF= Freefall

Discussion

Precipitation largely trickles through tree canopies in form of stemflow and throughfall (Van Stan et al., 2021). These flux corridors, symbolically described as "hydrologic highways", have been notably identified as transporters of ecologically significant biological and non-biological (chemical) content to the soil, as they play a strategic role in the air-plant-soil continuum (Friesen, 2020; Van Stan et al., 2021). Stemflow and throughfall therefore, have concomitant biogeochemical significance in terrestrial ecosystems (Van Stan et al., 2021). This study has shown a nutrient return order in the canopyfall of A. indica, D. oliveri and V. paradoxa and across all the tree species stemflow, in the form (K > Ca >Mg > NO_3-N^- > $PO_4^{3-}P$). This is comparable to Ndakara (2012), who reported nutrient returns for stemflow and canopyfall in the order (K >Ca >Mg >N >P >Na) and somewhat similar to the study of Fatoba (1997).

The nutrient return order of the canopyfall of P. africana (Ca > K > NO3⁻- N > Mg > PO³⁻-P) is comparable to the report of Xiangquing et al (2007), who identified annual output of nutrients in the run-off from young stands in the sequence (Ca > K> Mg> N> P). Calcium has been implicated in cellular mechanisms controlling light-sensitized gravitropism in plants, while potassium has functional roles such as plant growth, metabolism, and development (Roux and Serlin, 1987; Etesami et al., 2017; Trankner et al., 2018). Equally, potassium is involved in the activation of several enzymes responsible for plant processes such as starch synthesis and energy metabolism (White and Karley, 2010; Almeida et al., 2015; Etesami et al.,

2017; Trankner *et al.*, 2018). Magnesium plays a key role in fundamental processes such as photophosphorylation (ATP formation), partitioning and utility of photoassimilates, including sucrose loading in the phloem (Cakmak and Yazici, 2010).

The prominence of potassium, calcium, and magnesium as key nutrients in the tropical savanna, is clear and is a pointer to their ecological roles in soil fertility, base content and the structure and functioning of tropical vegetation (van der Heijden *et al.*, 2014; Lloyd *et al.*, 2015). In this regard therefore, it has been reported that tree species with more stemflow partitioning tend to have higher stemflow fluxes of potassium (Johnson and Lehmann, 2006), just as the potassium mobility factor in plants increases its leachability in stemflow (Momolli *et al.*, 2019).

Understory precipitation (canopyfall stemflow) generally showed and dominant nutrient returns over freefall. This corroborates similar reports from terrestrial ecosystem-based several studies (Balieiro et al., 2007; Perez-Marin and Menezes, 2008; Tan et al., 2018; Moslehi et al., 2019; Fadhilah et al., 2021). For the understory precipitation stemflow flux group, had а comparatively superior nutrient return over canopyfall, which corroborates for instance, studies that found higher stemflow fluxes of potassium in species with more stemflow partitioning (Johnson and Lehmann, 2006; Dick et al., 2018; Nsien et al., 2021).

The correlation spectrum within the understory precipitation fluxes (canopyfall and stemflow) of the five tree species for the cationic elements are quite notable. Positive correlation between canopyfall and stemflow is possibly due to the fact that canopy particulate matter, decomposing twigs and branches tend to increase nutrient content in canopyfall due to exudate washing. Furthermore, longer precipitation residence in canopies initiates stemflow with higher nutrient enrichment, from bark tissue leachability (Parker, 1983; Cornu et al., 1998; Levia and Herwitz, 2000; Johnson and Lehmann, 2006; Salehi et al., 2016; Van Stan et al., 2017; Koyejo et al., 2020). However, the inverse relationships identified between the canopyfall, stemflow and freefall in D. oliveri, P. biglobosa, P. africana and V. paradoxa suggest that higher rainfall volumes could lead to reduction in concentration levels (Momolli et al., 2019). For the anionic nutrients nitratenitrogen and phosphate-phosphorus, a quite converse diverse, multidirectional correlational pattern could suggest an unpredictability in terms of the effect of canopyfall on stemflow.

Conclusion

The study identified the significance of understory canopyfall and stemflow precipitation fluxes from tree cover, in the nutrient biogeochemistry of the tropical savanna ecosystem. This is also an indication of the ecological significance of tree cover. It is evident that rain-wash remains a key, direct nutrient transfer vehicle from A. indica, D. oliveri, P. biglobosa, P. africana and V. paradoxa tree species, to the savanna floor, thus contributing to sustainability of soil nutrient enrichment and fertility. It is indicative therefore, that the sustainable maintenance of tropical tree cover in woodland savannas and agroforestry initiatives, is inevitably the forward

approach to mitigating ecological degradation in terrestrial ecosystems.

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Ethiopian Journal of Environmental Studies and Management Volume 16 No.6, 2023

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