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Nutrient Release from Immersed Foliar Biomass during Caruachi Dam Reservoir Filling: Caroni River, Venezuela

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Abstract

Background: Decomposition process controls the release and the availability of essential nutrients, which affects the structure and the functioning of plant communities. Freshwater reservoirs are largely known to have impacts on the water quality, especially during the first phases of filling. The aim of the study was to conduct a nutrient release experiment where decomposition of fresh leaves and litter from vegetation of a low dry tropical forest was flooded. Selected species were Leguminosae species *Albizia glabripetala* (H. S. Irwin) G. P. Lewis & P. E. Owen (AG), *Bauhinia aculeata L.* (BA), *Centrolobium paraense* Tul. (CP) and *Piptadenia leucoxyllon* Barneby & J. W. Grimes (PL). Freshwater decomposition experiments were carried out at 50 cm depth inside nine floating containers in a protected area of the reservoir: litter (HJ), leaves of AG and BA (E2), and CP and PL (E3) were used. It was over 20 weeks period. Every week for two months and at week 20, a bag of each sample was extracted for analysis of Carbon, Ca, Mg, Na, K, P and S. **Results:** Results indicate that residual dry mass decreased by 71% for HJ, 81.4% for E2, and more than 86.8% for E3 after twenty weeks. The higher content of carbon (%) at the beginning of the experiment was E2 > E3 > HJ. After 20 weeks, the percentage of carbon loss was 2.09% for HJ, 3.02% for E2, and 1.69% for E3. S decreased between 50% - 60% during the first week; at 20 weeks, the remaining amount of S was 13% for HJ and E3 and 7% for E2. P showed a different pattern, where the second week was more important for the release. HJ and E3 followed the pattern of nutrient release: K > Mg > Na > Ca while E2 was K > Ca > Mg > Na. **Conclusions:** P and S release depends on the time of submergence and the species. Fresh leaves decay faster than necromass. Nutrient loss is higher than 50% for the three first weeks and seems constant between week 8 - 20. C and S concentrations incorporated in the reservoir can result in a high release of gases CH_4 and S_2 to the atmosphere. This study is the first publication in relation to nutrient release from the submergence of species in dry tropical forests.

Keywords

Decomposition, Nutrients, Litter, Leaves, Dam Construction

1. Background

Freshwater reservoirs in rivers are largely known to have impacts on the water quality, especially during the first phases of filling given the occurrence of important physicochemical reactions related to the nutrient release derived from the decomposition of the biomass present in the new lands flooded (Bresciani et al., 2019; Markad et al., 2019). The large release of methane is a reason why Fearnside (2016) has indicated that reservoirs in Amazonian countries can be considered methane pumps with large consequences to global warming. It is also the reason why it is recommended to do a complete clearing of the vegetation before the filling of a dam.

Decomposition controls the release of carbon as well as essential nutrients and the availability of them affects the structure and the functioning of plant communities (Bragazza et al., 2008; Junaedi et al., 2022). Leaves and litter decomposition has been roughly divided into three distinct processes: leaching, microbial action, and invertebrate feeding. Leaching mainly occurs in the early stage of decomposition. In aquatic ecosystems, leaching is more prominent because water is the major factor limiting the decomposition of the foliar material (Chen et al., 2021). This decomposition in freshwater ecosystems is a vital process linked to nutrient cycling, energy transfer and trophic interaction (Zhang et al., 2019). Hydroelectrical dam filling formed a reservoir with a new environment characteristic completely different from those that existed before, with alteration in the physical and chemical properties of the waterbody.

In the case of river impoundments, a lotic water system is changed to a lentic water system and increases the residence time (Song, 2018; Salem, 2021). The terrestrial ecosystem is replaced by an aquatic system with incorporation of soluble soil compounds and nutrients that are released by the decay of the terrestrial organisms, and pass into the water causing a series of imbalances in the neo-formed system. Leaves, trunks, and litter decomposition provide the aquatic system with a new amount of nutrients, as well as from the leaching of soils, that involves a complex set of processes including chemical, physical and biological agents acting upon a variety of organic substrates that are constantly changing (Song, 2018; Salem, 2021).

One of the greatest impacts of the construction of hydroelectric dams is the flooding of forests and other terrestrial vegetation while in cases of programmed deforestation of extensive areas, usually there is rapid regrowth. In this case, there might be CO_2 and methane emissions, considered greenhouse gases (Haya et al., 2002; Fearnside, 2016), as well as the presence of mercury methylation process by microorganisms involved in the decomposition of plant material, as well. The nutrient contribution to the aquatic system is evidenced by changes in water quality (Dezzeo et al., 1998; Bresciani et al., 2019; Markad et al., 2019). The flooding of a tropical forest results in many environmental changes, and this may be due to the use of oxygen available in water as part of the leaf decomposition process, resulting in the formation of hydrogen sulfide that affects the equipment used by the hydroelectrical companies as well as their influences on organisms (Fearnside, 1989; Lemos de Sá, 1992; Chen et al., 2021). In the Guiana Shield Rivers, there might be bioavailability of potential toxic elements (PTE's) bioavailability given by the characteristic acidity of their black waters, especially the Caroni River which is of high hydroelectric importance in the economy of Venezuela (Paolini, 1986; Rosales, 2003). Decomposition of plant tissue is a very important process within biogeochemical cycles, especially for nutrient-poor systems (Zhang et al., 2019; Souza e Brito et al., 2020). Phosphorous, Nitrogen and sulfur are important nutrients. When these cycles are altered, variations occur that lead the system to being oligotrophic or eutrophic. In this case, the systems are going to have an intake of nutrients above the normal, with excess of nutrients and abundance of macrophytes (Khan & Mohammad, 2014; Dubey &Dutta, 2020).

The chemical composition and decomposition of plant material from both terrestrial and aquatic plants are of great interest in order to obtain information on the nature of the substances they contain, their ability to conserve nutrients, assess the availability of nutrients, and account for the knowledge achieved on this subject, both their physical, chemical and biological aspects, their importance in the dynamics of matter and energy in ecosystems, as well as their relation to different environmental factors (Lidman et al., 2017; Zhang et al., 2019). The contribution of nutrients from the plant tissue, in decomposition process, is considered one of the most significant reservoirs within the biogeochemical cycles (Holmer, 2019). Especially those of species and ecosystems which are not part of a natural riparian system (i.e. riparian vegetation, wetlands) but will be inundated during the process of filling as the nutrients provided by their decomposition are not part of the natural nutrient budget of the river system (Wantzen et al., 2008).

This study assesses the chemical characteristics of carbon and nutrient release with respect to total dissolved carbon, the elements calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K) and the nutrients phosphorous (P) and sulfur (S) in the black waters of the Caroni river. The Caruachi dam reservoir during the first stage of flooding derived from the decomposition of the most abundant legume species in the dry forest, as well as from the litter of dry forest ecosystems vegetation types that dominate in the Caroni valley landscape in the Caruachi area, but are not part of the natural riparian system. A previous complementary publication reported the invertebrate, bacteria and fungi biological groups involved during the process of decomposition along the same experiment (Blanco-Belmonte et al., 2004).

The aim of this research is to demonstrate that in the filling of the dam reservoir, it is important to remove the vegetation and litter from the dry forest, because it means a lot of nutrient entrance to the water body and from an oligotrophic system immediately a system rich in nutrient is formed. The main findings were that from the label nutrient K was easier to break down for all the species, and from the three types of leaves, necromass was the one with lower decay than the foliar biomass.

2. Methods

2.1. Study Area Description

The study area, Caruachi dam in the Caroní River basin, is located between 3˚40' and 8˚40' of latitude North and between 60˚50' and 64˚10' West longitude, in the Bolivar state (**Figure 1**). The Caroni River is considered a black-water river, according to Sioli's classification (Sioli, 1984), due to the contribution of humic and fulvic acids, organic material carried by the river. These acids are formed by the decomposition of the organic material of plant tissue and acidic soils characteristic of the Guiana Shield (Paolini, 1986; Singh et al., 2020). The climate of the study area is tropical dry forest from Koppen, with an average temperature of 27˚C, and annual total precipitation of 1.200 mm seasonality distributed. The maximum rainfall occurs during the period May to September, where 65% of the total annual average falls.

The geological settings belong to Imataca Province, which is located at the northern end of the Guiana Shield characterized by mafic intrusive rocks, a

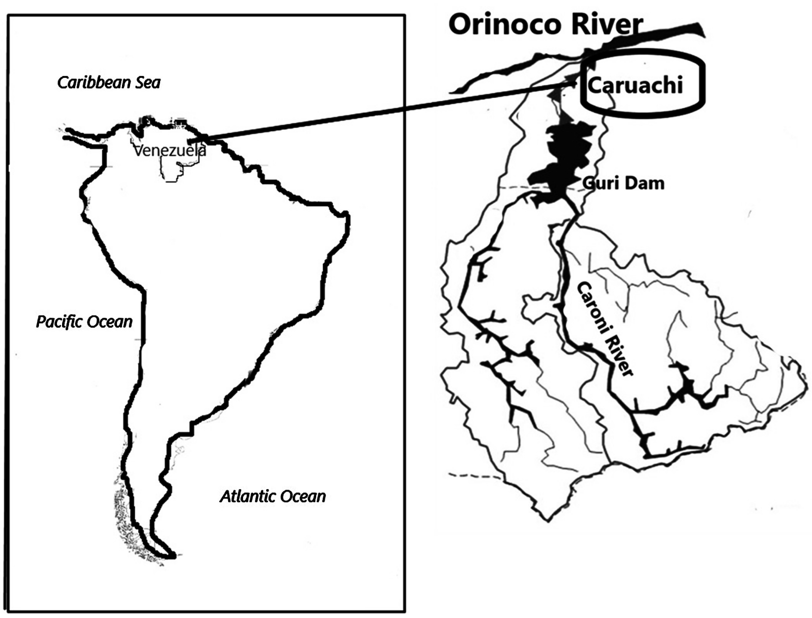


Figure 1. Study area, Caruachi Dam lower Caroni River, Venezuela and the complete area of the dam filing.

sedimentary cover represented by Plio-Pleistocenic sediments of the Mesa Formation and more recent Holocene sediments (González, 2002). The soils are old, deeply weathered, acid and of low natural fertility, and have been classified according to the USDA classification system as Ultisols (Fuentes & Madero, 1996).

Dominant vegetation types are tropical dry forest, savannas, gallery forests and successional scrubs (EDELCA, 2010). Leguminosae are the dominant tree species in the dry forest being among the most common species *Piptadenia leucoxyllon* Barneby & J. W. Grimes (PL), *Bauhinia aculeata* L. (BA), *Centrolobium paraense* Tul. (CP) and *Albizia glabripetala* (H. S. Irwin) G. P. Lewis & P. E. Owen (AG) (last identifications) which were selected for the study.

2.2. Sampling Procedure

Leaf and litter samples were randomly collected in 30 plots of 200 m^2 each for measurement of total litter biomass, and leaf per species. Organic carbon was estimated from biomass and litter subsamples. Three water decomposition experiments were carried out with triplicate samples located along the left border of the Caruachi embankment reservoir at the initial phase of the filling. They were organized within the upper 50 cm depth inside nine floating containers with 1 m separation along a line in a protected area of the reservoir

The decomposition bag technique was used (Swam, 2007; Bärlocher, 2020), where the samples were placed on nylon bags, represented by litter (HJ), leaves mix of *Albizia glabripetala* AG and *Bauhinia aculeata* BA (E2), and *Centrolobium paraense* CP and *Piptadenia leucophylla* PL (E3) and introduced into the water simulating the decomposition process of submergence of the forests during the reservoir filling, in March 2003. Litter bags (10 × 20 cm 0.5 cm mesh) were left under incubation at a field experimental station in the right margin of the reservoir (**Figure 1**). Each litter bag contained 5.00 ± 0.05 g (mean ± SD) of leaf material. The bags were distributed in three rigid structures (2 cm mesh) hanging from floating empty barrels, in turn anchored to land. Each structure was vertically aligned by 3 kg iron weights. At every collection of samples in the reservoir, *in-situ* measurements of the following water variables were carried out: temperature, pH, conductivity, and dissolved oxygen (DO) at 27˚C, using a multiparametric probe (Hatch Mod. 2511). After 1, 2, 3, 4, 5, 6, 7, 8 and 20 weeks of submersion, respectively, 3 bags representing replicates combinations of HJ, E2 and E3, were randomly retrieved, placed in polyethylene sealed bags and returned to the laboratory in portable coolers.

Every sampling period 3 leaf bags with 3 replicates were collected giving a final amount of 81 samples to be included in the analysis. Each litter and leaves mix of the plants from the sample collection were dried at 70˚C until constant mass dry mass of the original plant material was reached and the material from each collected bag were kept for chemical analysis. The oven dried material was milled. Total carbon was analyzed by the method of weight loss by ignition in oven (Zhang et al., 2014; Martínez et al., 2018). Total phosphorus was measured colorimetrically (Murphy & Riley, 1962; Chen et al., 2019) in samples digested with 4:1 H_2SO_4-$HClO_4$ mixture, with vanadium pentoxide as catalyzer. Total Sulphur was analyzed by dry acceleration with $BaSO_4$, where the S from the plant tissue is oxidate to sulphate (Tateyeva et al., 2018). Concentrations of magnesium, sodium, potassium, and calcium were determined after digestion with 4:1 H_2SO_4-$HClO_4$ mixture by atomic-absorption spectrophotometry.

2.3. Data Analysis

90 samples were analyzed for 7 parameters, with a total of 630 data result, after calculated the media there were 210 the data size. To explore decomposition periods, one-way analysis of variance (ANOVA) was used, where mass remaining and nutrient release during decomposition periods for each foliage type helps to assess the effects of the foliage types and decomposition period. The statistical analyses were carried out using statistical package for social science (SPSS 26.0) for Microsoft Windows.

3. Results

The *in-situ* values of the physicochemical parameters: temperature, pH, conductivity, and dissolved oxygen (DO) which area characteristics of a black-water freshwater system were presented in **Table 1** (Sioli, 1984; Paolini, 1986; Vegas-Vilarrúbia et al., 1988; Anwana et al., 2020). Losses in dry weight of the samples of fresh leaves combination E2, E3 and litter (HJ) over the 20 weeks period are shown as a percentage of the original remaining dry weight in **Figure 2(a)**. At the end of 20 weeks, the mass remaining was 29% for HJ, 18.6% for E2 and 13.2% for E3. The rate of mass loss for the first week indicated that 27.2% for HJ, 21% for E2 and 36.2% for E3 while during the subsequent weeks the loss between the second and eighth weeks was lower in all cases 0.4% - 6% (HJ), 0.4% - 14.8% (E2) and 4.8% - 17.6% (E3). In the case of the last sample collected the losses in dry weight between de eighth and twenty weeks was 17.2%, 31.4% and 4%, for HJ, E2 and E3, respectively.

Regarding the release of carbon, it was observed that the higher release of carbon (%) at the beginning of the experiment was 0.8% for E2, 0.3% for HJ and 0.1% for E3 as showed in **Figure 2(b)**. For the decomposition after 20 weeks the percentage of carbon release was 2.09% for litter (HJ), 3.02% and 1.69% for fresh

Table 1. *In-situ* physicochemical parameters.

Variable	N	Mean	Range
Water temperature (˚C)	9	28.54	28.9 - 29.2
Water conductivity (µS/Cm at 27˚C)	9	9.66	8.72 - 11.0
pH	9	6.41	6.1 - 6.67
O_2 (mg/L)	9	6.65	6.4 - 6.8

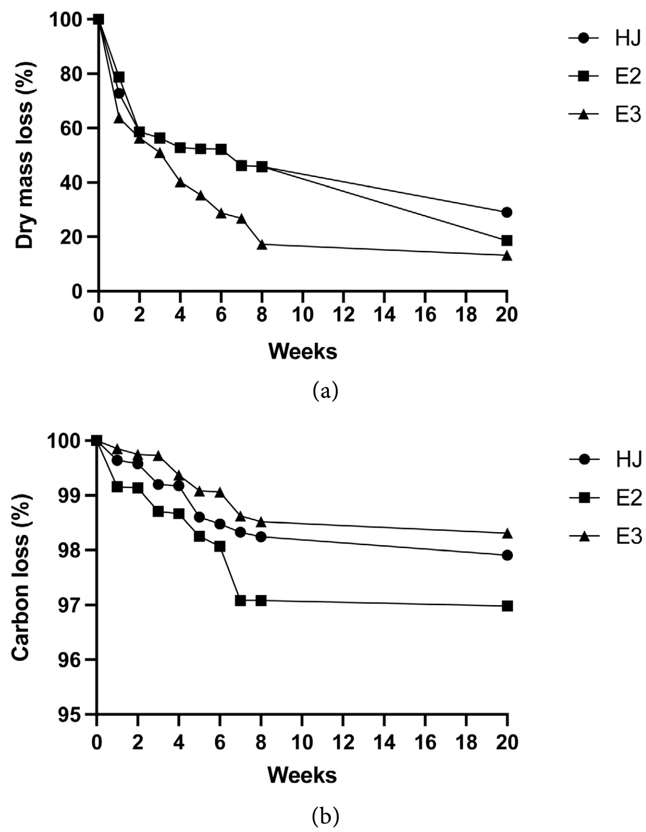
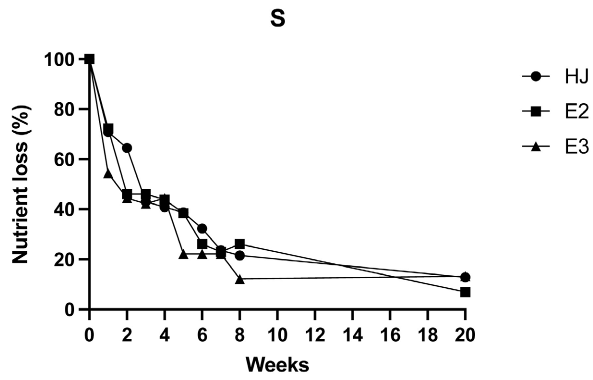


Figure 2. (a) Dry mass loss of fresh leaves *Albizzia* and *Bauhinia* (E2), *Centrolobium* and *Piptadenia* (E3) and litter (HJ) during the period of the decomposition experiment. (b) Carbon percentage lost for litter (HJ) and fresh leaves (E2, E3).

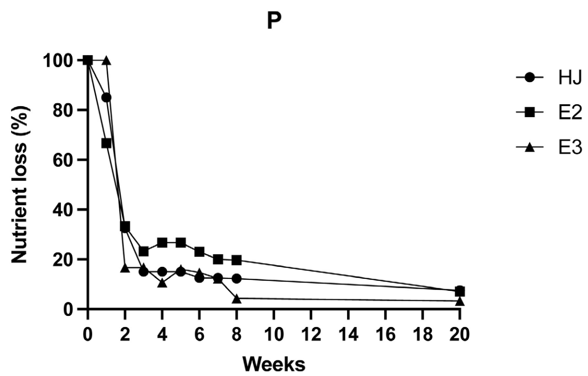
leaves, E2 and E3 respectively. During the decomposition experiment the higher carbon release was as following E2 > HJ > E3.

Table 2 showed the initial nutrient mass per unit weight (nutrient concentration, mg/g) of the fresh leaves from the single species as well as from the mixed species of leaves and litter which were placed in the litter bag. In plant tissue the elements Ca, Mg, Na K, come from a soil mineral formation, P that can be uptake by mycorrhizae from soils while S is derived from atmospheric sources (Jobbágy & Jackson, 2004; Pandey, 2015). For the mixed species and litter there are no significant differences between the nutrient's concentrations: P, S, and the elements Na, Ca, Mg, K. Nutrient loss in species fresh leaves (E2, E3) and litter (HJ) chemistry during the period of decomposition are shown in **Figure 3** and **Figure 4**.

From the nutrients P and S, the last was very conservative and showed a linear relationship with mass loss ($r^2 = 0.852$, $p < 0.01$) followed by the phosphorus ($r^2 = 0.901$, $p < 0.01$) for HJ and E3. The pattern of S loss showed a relatively different tendency than that of the other elements. The initial amount of S decreased 50% - 60% during the first week; in the subsequent sampling period the rest of this element was lost gradually, and at the end of the 20 weeks the remaining amount of S was 13% for HJ and E3 and 7% for E2 (**Figure 3(a)**). With respect



(a)



(b)

Figure 3. Nutrients loss for nutrient S (a) and P (b) in fresh leaves *Albizzia* and *Bauhinia* (E2), fresh leaves *Centrolobium* and *Piptadenia* (E3) and litter (HJ).

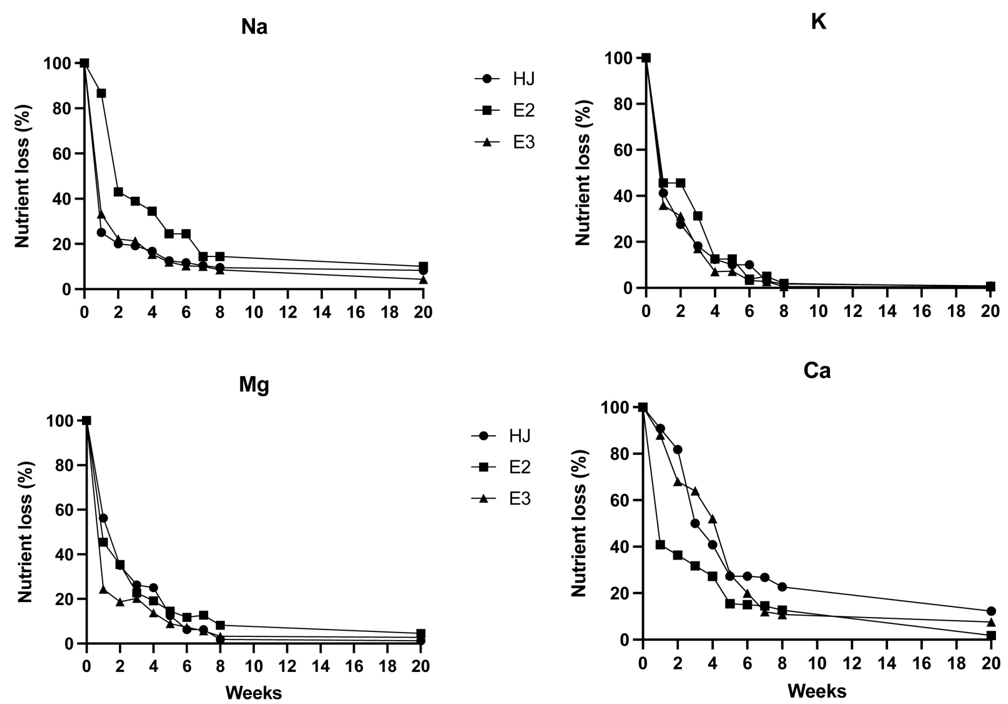


Figure 4. Macronutrients loss Na, K, Mg, Ca for litter (HJ), fresh leaves *Albizzia* and *Bauhinia* (E2) and fresh leaves *Centrolobium* and *Pithecellobium* (E3).

Table 2. Initial nutrients and macroelement concentrations studied in the individual leaves per species and the mixed species leaves used for the decomposition experiment. HJ: Litter; E2: *Albizzia* + *Bauhinia*; E3: *Centrolobium* + *Piptadenia*.

Species	Nutrients mg/g dry weight		Macroelements mg/g dry weight			
	P	S	Na	K	Mg	Ca
Bauhinia	0.0078	0.0003	0.0223	0.0175	0.0453	0.0940
Albizzia	0.0200	0.0004	0.0225	0.0113	0.0433	0.0199
Centrolobium	0.0102	0.0005	0.0220	0.0145	0.0450	0.1105
Piptadenia	0.0282	0.0005	0.0040	0.1940	0.0540	0.0698
HJ	0.043 ± 0.012	0.0009 ± 0.0008	0.0120 ± 0.0020	0.17 ± 0.02	0.160 ± 0.030	0.22 ± 0.09
E2	0.027 ± 0.018	0.0013 ± 0.0003	0.0090 ± 0.0030	0.16 ± 0.01	0.110 ± 0.010	0.22 ± 0.09
E3	0.031 ± 0.012	0.0009 ± 0.0001	0.0117 ± 0.0008	0.17 ± 0.02	0.123 ± 0.002	0.25 ± 0.16

to phosphorus, the first week was the less release for the three species, presumably due to leaching; in the following 7 weeks the amount of this element remained practically unchanged, and afterwards decreased gradually to 7% for HJ and E2, 3% for E3, at the end of the 20 weeks period (**Figure 3(b)**).

The pattern of element loss was relatively similar between the species, $p > 0.05$ no significative difference was observed between plant species and litter. The element with a higher release rate was K for fresh leaves and litter, showed a strong correlation with mass loss ($r^2 = 0.923$, $p < 0.01$), because potassium generally existed as metal ion, and thus is more easily released (Jacobson et al., 2011; Du et al., 2020). The element with higher entrance during the first two weeks was Na ($r^2 = 0.600$, $p > 0.05$). After the fourth week potassium was the element, which was most rapidly lost which is similar to the results of Dezzeo et al. (1998), followed by magnesium ($r^2 = 0.638$, $p < 0.05$) (**Figure 4**). Mg and Ca showed a decay ($r^2 = 0.638$, $p < 0.05$) in E2. In the case of K after the first four weeks less than 10% of K remained in E3 leaves, 13.7% for E2 and 12.4% for HJ.

HJ showed the following pattern of nutrient loss, comparing the initial amounts and the fourth and eighth week, expressed as a percentage of loss of concentration in 20 weeks: K > Mg = Ca > Na E2 introduces to the pattern K > Ca > Mg > Na. E3 also coincides with HJ, K > Mg > Na > Ca.

4. Discussion

Physicochemical values are similar to the values reported by Sánchez and Vásquez (1989) for the Caroni River and Anwana et al. (2020) for black waters ecosystem, where pH fluctuated between 5 and 7 and conductivity between 3 and 11µS/cm. As the experiment was carried out at the beginning of the dam filling process, the forest vegetation was not yet submerged and therefore there were not expected changes to occur in pH, conductivity and DO.

4.1. Dry Mass and Carbon Loss for Fresh Leaves (E2, E3) and Litter (HJ)

The difference in the rate of mass loss between the first week and the other weeks may have been due to the rapid leaching of soluble components, leading to decreased leaf quality in the early stages of decomposition (Chen et al., 2021). In addition, aquatic microorganisms and invertebrates play an important role in the process of foliage decomposition as was demonstrated in the parallel research (Blanco-Belmonte et al., 2004). A process that has also being referred by many other researchers along the world (Graça, 2001; Leroy & Marks, 2006; Tiegs et al., 2013; Barathy et al., 2020).

The E3 species mixture is the one that loses the higher weight value for the first week, which shows the rupture of cell walls and nutrient release faster for E3 than other species, this can be explained by two reasons, higher content of soluble inorganic material (Webster & Benfield, 1986; Giweta, 2020) and the type of foliar species which is leached quickly by water or by fixation and microbial activity (Franklin et al., 2020; Cuassolo et al., 2021), then for HJ and finally for E2. The decomposition process depends on the type of species as well as on other factors such as precipitation and temperature (Tuomi et al., 2009; Krishna & Mohan, 2017; Porre et al., 2020) in addition to microorganisms such as bacteria, fungi and macroinvertebrates, which are associated with the particular species. In the same experiment during the first 4 weeks of measurements, Blanco-Belmonte et al. (2004) reported an increase in macroinvertebrate the first week of measurement following a decay while along the same periods there was an increase in bacteria cellulolytic and pectinolytic functional groups.

The range of mass loss was higher the first week for all species, which indicates a potential for a rapid enrichment of nutrients in the reservoir, then a slow intake is observed for the following weeks. It should be noted that the behavior is similar for the litter and the two species combinations studied. The weight loss observed for the leaves in the first weeks is probably due to leaching of the soluble material (Dezzeo et al., 1998; Edwartz, 2018). This result could reflect temporary drastic changes in the aquatic ecosystem, a nutrient-poor river, an oligotrophic system, due to the slow decomposition range of organic material mainly associated with polyphenols and polymers of trunks, lignin and cellulose (Fenner & Freeman, 2020). It is in general accepted that important changes in the physical and chemical characteristics of the leaves take place in the first few days to weeks of decomposition (Yule & Gomez, 2009; Rinkes et al., 2014; Trevathan-Tackett et al., 2020). In this period the plant detritus rapidly begins to lose soluble organic and inorganic materials mobilized either by passive physical processes or by decomposer activity. Likewise, Collins et al. (2019) suggested that after initial loss, the organic matter becomes more resistant to decay mainly caused by the relative accumulation of condensed or polymerized polyphenols with very slow rates of decomposition. During week 20, the percentage of dry weight loss for E3 is 87%, E2 82% and HJ 71%, with these results it could be said that the decomposition of fresh leaves is faster than litter, therefore the supply of nutrients to this aquatic system comes first by foliar biomass and then by the necromass.

Carbon release showed that before the decomposition experiment took place the amount of carbon was higher in the fresh leaves (E2, E3) than in the litter sample (HJ), and after the release of carbon in the water body, E2 and HJ had a higher range of decay than E3. For all the samples the rate of decay did not exceed 3.05%.

4.2. Nutrient Release from Fresh Leaves (E2, E3) and Litter (HJ) during Decay

The P in HJ is quite mobile compared to E2. The S showed a fairly balanced pattern for the three samples, always being the remnant in the plant tissue during the process of decomposition. This can explain the formation of HS (hydrogen sulfide), from odors after the eighth week.

K is a highly mobile, readily leached ion, usually occurring in amounts in excess of decomposer demand (Dezzeo et al., 1998). The rapid rate of K loss shows the dominance of the leaching process (Bai et al., 2022). Magnesium is relatively leachable (Osono & Takeda, 2004; Lalremsang et al., 2022), its initial loss occurred rapidly, and at the end of the fourth week the original amount of Mg was reduced to 25% for HJ, 19.1% E2 and 13.8% for E3. In contrast to the rapid loss of sodium, followed by potassium and magnesium, the loss of calcium during the first month was relatively slow: 40.7% for HJ, 52% for E3 but 27.3% E2 of the initial amount of Ca remained in leaves at the end of this month (**Figure 4**). Ca is little susceptible to leaching and shows patterns of increase and decrease with the time (Osono & Takeda, 2004; Lalremsang et al., 2022).

K shows greater mobility than other ions (Osono & Takeda, 2004) and is demonstrated in the leaching process (Andrews et al., 2021). Then the Mg shows greater mobility in the species mixtures (E2 and E3) as opposed to HJ. The Mg is relatively soluble, in the leaf it is found forming part of the chlorophyll molecule but shows a higher concentration loss than the other nutrients. This coincides with what was observed by Dezzeo et al. (1998) in the Caura. E3 shows a decomposition process greater than HJ and E2, this is evidenced by the physical characteristics of the leaves each week when removing the samples and in the chemical process with nutrient concentrations, the loss is greater for this mixture of species. For HJ there is greater loss in the eighth week and for E2 the decomposition is accelerated from the second month to week 20. Instead in E3 it comes out after Mg and K which are the most soluble. The Ca shows a fairly varied pattern for the samples, in fact a more specific study would be needed with respect to it to be able to give an explanation.

Regarding the decrease in nutrient concentrations, a similar behavior is observed for HJ, E2 and E3 due to the decomposition process (**Figure 3** and **Figure 4**). Na and K are the first elements to come out of plant tissue, as they are soluble in water, they are easier to be leached. The K is not a component of molecular or macromolecular plant structure, it is present in living organisms as free K and is one of the most abundant nutrients in leaf biomass (Hytönen et al., 2019; Sardans & Peñuelas, 2021) also considered within the soluble elements and in the process of decomposition usually disappears before sodium and calcium. This is because K has the largest ionic radius than Ca and Na its electrical density and electrostatic interactions decrease with the charge-radius of the ion (Kakkar et al., 2006; Zhang et al., 2020). K has less interference capacity with biological functions in cytoplasm cell media, the strength of the solvation bond with water molecules (coordination complex, chelate formation) is lower, and its mobility capacity in water solution is higher than Na and Ca (Sardans & Peñuelas, 2021). In our experiment we can observe this characteristic. Na are classified as a functional nutrient in low concentration and support maximal biomass growth, ability to replace K being an osmoticium for cell enlargement and as an accompanying cation for long-distance transport (Subbarao et al., 2003; Lourenço Jr. et al., 2021). Ca is related to cell walls and membrane stability, their regulation, is important in the creation of new cells, involved in more plant functions and indispensable in plant nutrition (Thor, 2019; Sardans & Peñuelas, 2021), in the decomposition process, a slower behavior is observed than for Na and K, the leaching process is to a lesser extent. Mg forms a structural part of the chlorophyll molecule and activates many enzyme systems, which is why it is expected to be one of the last minerals to leave the plant tissue, it abandoned the tissue simultaneously with the Ca.

For the nutrients, S and P are contained in plant tissue in few concentrations because these systems are poor in these elements. The function of P has mainly to do with the nucleic acids contained in the chromosomes and the energy associated with the ATP of plants (Thakur et al., 2014; Zhang et al., 2020). Sulphur is associated with proteins (Procházková et al., 2016; Hendrix et al., 2017). In the process of decomposition, the S binds to the protons of the H^+ water forming hydrogen sulphide that generates a very characteristic and fetid odor, in addition to binding with the oxygen of the water it can form sulphate ions and in turn acids that contribute to lowering the pH of the aquatic system. Bonilla et al. (2020) did a study of the nutrient release of species from flooded forests of varzea and igapo in the Amazon river basin. In that case the results are related to the natural biochemical processes of decomposition that relate to the water chemistry conditions. In this study however it is shown for the first time the potential nutrient release from the submergence of legume species in dry tropical forests. Although there was the idea to continue the work with the hydroelectrical enterprise in order to do the calculations of the release of nutrients expected per ha of the reservoirs flooded vegetated border during the filling, this data has not been yet made available.

5. Conclusion

The process of decomposition of the plant tissue of tropical forests, in the formation of reservoirs, is directly related to the water quality characteristics such as pH, conductivity and temperature, in addition to microorganisms such as macroinvertebrates, bacteria and fungi that help the process of fragmentation of organic matter and mineralization of nutrients introduced by the flooding of forests. The legume species mix E3 = *Centrolobium paraense* and *Piptadenia leucoxyllon* showed a greater dry weight loss than the legume species E2 = *Albizzia glabripetala* and *Bauhinia aculeata*. Similarly, the Litter HJ presented the lower decay. This indicates that the process of decay also depends on the type of species being considered. The foliar biomass of the legume species E2 and E3 provides nutrients to the reservoir faster than the litter necromass, HJ indicating the importance of deforestation but at the same time not allowing the regrowth of the forest vegetation before the filling of the reservoir. Nutrient loss is higher than 50% for the three first weeks and seems constant between week 8-20 for E3, E2 and HJ. The high C and S incorporated in the reservoir can result in high release of gases CH_4 and S_2 to the atmosphere which is a very important reason for the appropriate management of this potential regrowth.

This study is the first publication in relation to nutrient release from the submergence of species in dry tropical forests.

This study's limitation was to only perform with foliar biomass and necromass, it will be useful to understand the nutrient dynamic with the wood and branches decomposition in the dam reservoir filling.

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Ethical Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors.

Consent for Publication

All individuals included in this research gave written informed consent to publish the data and images contained within this case report.

All individuals provided written informed consent to publish the data contained within this article.

Availability of Data and Material

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request. All data produced from this study are provided in this manuscript.

Conflicts of Interest

The authors declare that they have no competing interests.

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Author's Contributions

Judith Rosales (JR) conceived and designed the experiment. Aracelis Narayan (AN) performed the experiment. Aracelis Narayan & Judith Rosales analysed the data. Aracelis Narayan & Judith Rosales wrote the manuscript; Judith Rosales provided editorial advice. All authors have read and approved the manuscript.

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List of Abbreviations

AG = *Albizia glabripetala*
AN = Aracelis Narayan
ANOVA = Analysis of variance
ATP = Adenosine triphosphate
BA = *Bauhinia aculeata*
$BaSO_4$ = Barium sulphate
˚C = Celcius
C = Carbon
Ca = Calcium
CH_4 = methane, gas
cm = centimeters
CO_2 = Carbon dioxide
CP = *Centrolobium paraense*
CVG = Corporación Venezolana de Guayana
DO = Dissolved oxygen
E2 = leaves of AG and BA
E3 = leaves of CP and PL
EDELCA = Electrificación del Caroni
Figure = Figure
g = grams
H^+ = protons
HJ = litter
$HCLO_4$ = Perchloric acid
H_2SO_4 = Sulfuric acid
JR = Judith Rosales
K = Potassium
kg = kilograms
Lab = laboratory
m^2 = square meters
mg = milligrams
Mg = Magnesium
Mod. = model
mm = millimeters
Na = Sodium
P = Phosphorous
p = value of significance level
pH = water acidic/basic measure
PL = *Piptadenia leucoxyllon*
PTE's = potential toxic elements
r^2 = correlation coefficient
S_2 = sulfur gas
S = Sulfur

SD = Standard deviation
SPSS = Statistical package for social science
UNEG = Universidad Nacional Experimental de Guayana
USDA = United States Department of Agriculture