NUTRIENT CYCLING UNDER ISOLATED EXOTIC TREE STANDS IN THE RAINFOREST ZONE OF SOUTH-SOUTH NIGERIA

BY

EMMANUEL OFUDJAYE NDAKARA
B.Sc. (Delsu), M.Sc. (Ibadan)
SI No.:130974

A THESIS IN THE DEPARTMENT OF GEOGRAPHY
SUBMITTED TO THE FACULTY OF SCIENCE IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY OF THE
UNIVERSITY OF IBADAN

November, 2014

ABSTRACT

Cycling of nutrient elements by exotic tree species is becoming increasingly important to the sustenance and productivity of rainforest environment. Apart from the provision of shade and fruits to rural farmers, the incorporation of these exotic tree stands into farmland helps to return nutrients to the soil. Despite the importance of exotic trees in the rainforest environment, information on nutrient cycling under individual tree stands in south-south Nigeria has not been adequately documented. In this study, the cycling of nutrients under isolated exotic stands of *Terminalia cattapa*, *Mangifera indica* and *Persea gratissima* in Orogun, Ughelli North Local Government Area, south-south Nigeria, was therefore investigated.

Litterfall, rainwash (throughfall and stemflow) and soil samples were collected from 15 stands of each of the three exotic tree species as well as 15 control plots in the rainforest. Litterfall and rainwash were collected daily for a year. Litterfall was collected with 1m² litter traps, throughfall and incident rainfall with funnel-type collectors; and stemflow with ¾ mm hose wound round the tree trunks. Soil samples were collected from 0-15 cm and 15-30 cm depth using core sampler. Nitrogen, phosphorus and potassium content of samples of litter, rainwash and soil, as well as soil organic matter were analysed using standard techniques. Descriptive statistics and ANOVA were used to compare nutrients returned to soil by the isolated trees and the control via litterfall and rainwash; while soil nutrients were correlated with litterfall and rainwash.

From the stands of *T. cattapa*, *M. indica*, *P. gratissima* and the control, litter productions were 83.0, 76.5, 60.2 and 77.3 g/m²/yr; annual throughfall volumes (%) were 89.2, 88.6, 91.0 and 84.2; while stemflow volumes (%) were 6.5, 6.2, 7.6 and 7.3 of the incident rainfall (4325mm). The nitrogen returned to the soil via litterfall was 5.7±1.4, 3.4±0.4, 2.4±0.1 and 9.1±1.7 kg/ha/yr respectively for *T. cattapa*, *M. indica*, *P. gratissima* and the control. The corresponding values of phosphorus returned in litterfall were 0.7±0.2, 0.5±0.1, 0.4±0.1 and 0.6±0.1 kg/ha/yr; while for potassium were 4.9±1.3, 2.6±0.2, 2.1±0.4 and 3.4±0.8 kg/ha/yr. The potassium returned via throughfall for the isolated trees and the control were 10.6±5.9, 9.5±5.9, 7.4±4.4 and 8.8±5.7 kg/ha/yr; while the corresponding values of potassium returned via stemflow were 0.7±0.6, 0.3±0.3, 0.4±0.3 and 0.7±0.6 kg/ha/yr respectively. Nitrogen, phosphorus and potassium returned to soil via litterfall, throughfall and stemflow varied significantly ($p<0.01$) amongst the isolated exotic trees and the control. Litterfall, throughfall and stemflow accounted for 54%, 40% and 6% of the total quantities of nutrients returned to soil respectively. Litter production and soil organic matter correlated positively under *T. cattapa* ($r=0.8$), *M. indica* ($r=0.8$), *P. gratissima* ($r=0.8$) and the control ($r=0.9$). Soil nitrogen, phosphorus and potassium correlated positively with litterfall ($r\geq0.2$), throughfall ($r\geq0.1$) and stemflow ($r\geq0.5$) respectively.

Isolated exotic trees over time returned nutrients to the soil, thereby improving soil nutrient status and sustaining soil productivity in the rainforest environment.

Keywords: Isolated exotic trees, Litterfall, Nutrient cycling, Rainforest, Rainwash.

Word count: 475

CERTIFICATION

I hereby certify that this work was carried out by Emmanuel O. Ndakara in the Department of Geography, University of Ibadan, Ibadan.

………………………………… …………………………

Supervisor **Date**

Albert O. Aweto
Professor of Geography
Department of Geography
Faculty of the Social Sciences
University of Ibadan, Ibadan, Nigeria.

ACKNOWLEDGEMENTS

My deepest sense of appreciation goes to the Almighty God who made everything regarding this programme a success. I am grateful to my supervisor, Professor A.O. Aweto, who was always there for me to offer perceptive suggestions and advice during the course of this research. I benefited greatly from working under him and I gratefully acknowledge his invaluable contributions and especially his efforts made to travel the long distance from Ibadan to inspect my field data collection exercise in Delta State; constant solutions offered whenever I reached him with problems regarding my research especially during the period of my laboratory analyses of samples. Words alone are not enough to thank you for all your assistance regarding this work. You are a shoulder to cry on. It is my sincere prayers that the good LORD, who knows your very needs, should reward you adequately.

Many thanks to all my lecturers in the Department of Geography, in particular, Prof. A.S. Gbadegesin, Prof. Adejumoke A. Afolayan, Prof. S.I. Okafor, Prof. B. Ayeni, Dr. Ibidun O. Adelekan and Dr D. D. Ajayi, for their perceptive suggestions and encouragement. I appreciate you all for your brilliant observations and suggestions towards the success of this work. May God protect you in health and wisdom to actualize your dreams.

To my dear mother, Mrs. Mary Ndakara, I love you dearly. Your usual zeal to know the stage of my research has been a vital source of encouragement to the success of this work. May God strengthen you to enjoy the fruits of your womb. To my dear brother, Barr. (Chief) B.O. Ndakara, you have been a father and a father indeed. Words are really not enough to appreciate you. May the peace of the Almighty God remain with you. Also to my cousin, Mr. E. Emenuwe, you gave me an unforgettable financial assistance at a particular time I was financially trapped at school during the course of this programme. God will reward you accordingly.

I owe much to my darling wife Mrs. Joy Elohor Ndakara, and our lovely children Emmanuella Eseoghene, Jerry Oghenefejiro and Jeffrey Oghenemaro (the Ndakaras). Thanks for your tolerance, understanding and moral supports throughout the course of this research. At certain times you showed that I was not always free to attend to you guys at home, and I felt bad because there were marked limits to the attention I could offer to you within the research period. However, and interestingly, as the Ndakaras got to know why I was always on reading table without much attention to them, they started calling me “doctor”. This was the height of it, and it really inspired me. I love you guys!

To my Geographical fathers, Prof. O. Ekanade, Dr S.I. Efe, Dr A.O. Atubi and Dr A.A. Abotutu. I am grateful to you for your moral supports and daily encouragement towards the success of this research. I shall remain ever grateful to Dr A.O. Atubi who loaned me some money so as to meet up with my proposal defense at a time I was financially stranded. My academic mentor, Dr A.A. Abotutu, I cannot thank you enough. Your everyday quest to know the position of my research was a major source of inspiration towards the success of this work. You monitored my progress all through the period of this study, and inspired me to move faster at the times my paces appeared retarding, owing to my associated commitments as a lecturer. At certain times, I was afraid not to disappoint him so I kept working with several months of “no sleeping”. Because of this, for good 8 months I slept for only 2 hours per day (since I must satisfy my primary assignment as a lecturer and a family man).

I wish to sincerely thank Mr A. I. Aghogho, the laboratory technician in the Department of Chemistry, Delta State University. He assisted me in the analyses of samples for this study. I also thank my field assistants Messrs Augustine Okwuazu, Ernest Odivwri, Ufuama Warri, Samuel Olo and Kizito Obodeke. May God reward you adequately. Above all, I wish to thank God who supplied all the materials and human resources for this research.

Emmanuel O. Ndakara
November, 2014

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

In tropical rainforests, plants and soils are in equilibrium involving an almost closed cycling of nutrients which is achieved by a very high rate of litter production, rapid mineralization and a rapid attainment of equilibrium with respect to organic matter relationships (Bernherd-Raversat, 1987; Vitousek and Sanford, 1986; Terborgh, 1992). However, whenever the forest is cleared for cultivation, this plant – soil relationship is disrupted irrespective of whether field or tree crops are planted (Adejuwon and Ekanade, 1988). Even after tree crops in plantations have matured, with their characteristics closed canopy, environmental degradation is not arrested, at least when compared with a mature tropical rainforest (Ojeniyi and Agbede, 1980; Adejuwon and Ekanade, 1988). Therefore the replacement of tropical rainforests with plantations of exotic tree species does not maintain the equilibrium which the native rainforest does. In this regard, it becomes imperative to study nutrient cycling under different tree species in order to account for the contribution of nutrient elements by tree stands to the soils underneath.

Plants and soils in the rainforest ecosystems are closely related, and they influence one another (Nye and Greenland, 1960; Ekanade, 2007). Plants get their nutrients and moisture from the soil in which they grow. As the plants develop, they shed their leaves and branches as litter which decays to enhance the nutrients of the soil that are again used up by plants, a process known as nutrient cycling (Nye and Greenland, 1960; Proctor *et al*., 1983; Chuyong *et al.*, 2004; Pragasan and Parthasarathy, 2005; Wood *et al.*, 2006). Nutrients returned to the soil through litterfall, stemflow and throughfall help to maintain soil fertility by increasing the quantities of the nutrient elements in the soil (Ojeniyi and Agbede, 1980; Jordan, 1985; Muoghalu *et al*, 1993; Muoghalu *et al.*, 1994; Muoghalu and Oakhumen, 2000; Hermansah *et al*., 2002; Perez *et al*., 2003). Dust accumulation on leaves and branches, transported to the soil by throughfall and stemflow is suggested as an important input of mineral nutrients and nitrogen (Parker, 1983; Escudero *et al.*, 1985; Newson, 1997; Ward and Robinson, 2000).

Therefore, there is a link between the soil and plant cover regarding cycling of nutrient elements. The plant cover has always served as an indicator of soil status, thus Chandler (1984) opined that the key to the survival of plant species in forest communities lies mostly in the efficient cycling of nutrient elements.

In the rainforest zone of southern Nigeria, exotic tree plants such as Mango (*Mangifera indica*), Indian almond (*Terminalia catappa)* and Avocado pear (*Persea gratissima*) are planted to produce fruits and shade for resting places within the settlements and surrounding environment. Many of the tree stands are found in isolation (i.e. their canopies are separated from one another) since they are not cultivated in plantations. Although the economic importance of these trees are known, no effort has been previously directed to the consideration of their ecological implications in terms of nutrient cycling, their effects on the rainforest soils, and their viability in the environment after the natural plant covers have been cleared in the wetter rainforest ecosystem of southern Nigeria.

In nutrient cycling, the returns of nutrient elements have been observed to vary with the floristic composition of plant cover (Hermansah *et al.,* 2002; Pypker *et al.*, 2005). The amount of nutrients returned from trees to the soil will therefore vary depending on the type of tree in question, as well as their distribution pattern. Also, different tree species exert varying influence on both physical and nutrient characteristics of the rainforest soils (Muoghalu and Oakhumen, 2000; Ekanade, 2007). However, different studies as conducted by Nwoboshi, (1985), Boettcher and Kaliz (1990), Weltzin and Coughenor (1990), Dunham (1991) and Ekanade (2003), have revealed that not every tree species has significant impact on the improvement of soil organic matter, exchangeable cations, build-up of the extractable micronutrients–iron, copper, manganese and zinc under their canopies. Low organic matter concentration and nutrients in soil underneath tree canopies is due possibly to frequent cultivation and burning of the vegetation prior to cultivation as opined by Akpokodje and Aweto (2007). Indeed, the extent to which plant communities are determined by resource availability is central to ecosystem studies, but patterns of small-scale variation in resource availability are poorly known.

Essentially, different studies on nutrient cycling with respect to litterfall, stemflow and throughfall have been conducted in different parts of the world. Nye (1960) examined the organic matter and nutrient cycles under moist tropical forests in Ghana; Parker (1983) studied throughfall and stemflow in forest nutrient cycle; Veneklaas and Klemmendson (1991) studied litterfall and nutrient fluxes in two montane tropical rainforests in Colombia; Bernhard-Reversat (1993) examined the dynamics of litter and organic matter at the soil litter interface in fast-growing tree plantation in Congo; Soulsby and Reynolds (1994) examined the chemistry of throughfall, stemflow and soil water beneath oak woodland and moorland vegetation in Mid-Wales; Hermansah *et al.* (2002) studied litterfall and nutrient flux in tropical rainforest of west Sumatra in Indonesia; Perez *et al.* (2003) investigated litterfall dynamics and nitrogen use efficiency in two evergreen tropical rainforests of southern Chile; Goller (2005) examined the biogeochemical consequences of hydrologic conditions in a tropical montane rainforest in Ecuador; Pragasan and Parthasarathy (2005) examined litter production in tropical dry evergreen forests of south Indian; while Wood et al (2006) investigated the determinants of leaf litter nutrient cycling in a tropical rainforest in Costa Rica. None of these studies examined the aspect of nutrient cycling with respect to litterfall, stemflow and throughfall in isolated tree stands. Also, in the Nigerian rainforest ecosystems, some of the studies conducted by Muoghalu *et al.* (1993), Muoghalu et al (1994), Muoghalu and Oakhumen (2000) were conducted on drier natural rainforest ecosystem; whereas the studies by Nwoboshi (1985), Oladoye *et al.* (2007) and Adedeji (2008) were conducted on plantation ecosystems. From these studies however, the contributions of individual tree stands to the soil in nutrient cycling were not effectively ascertained due to close canopy influence. Therefore, the results of such studies cannot provide a rational basis for understanding of nutrient cycling under isolated tree stands.

This study therefore, presents an assessment of nutrient returns to the soil through rainwash and litterfall, with special regards to seasonal variations in nutrient flux under isolated exotic tree stands. Also, since the earlier studies in Nigeria were conducted on the drier rainforest ecosystem (Muoghalu *et al.*, 1993; Muoghalu *et al.*, 1994; Muoghalu and Oakhumen, 2000), this study therefore presents an insight on the returns of nutrient elements through stemflow, throughfall and litterfall in the wetter rainforest ecosystem.

This study becomes necessary, and it is perhaps, the first research on nutrient cycling in isolated tree stands in the rainforest zone of south-south Nigeria. However, the choice of *Terminalia catappa* (Indian almond), *Mangifera indica* (Mango) and *Persea gratissima* (Avocado pear) species was determined by the differences in their crown architecture, stem and branch morphology, leaf size and arrangement. Canopy cover, tree size and tree species are known to affect rainwash (Pypker *et al.*, 2005). Expectedly, only the tree stands in isolation were chosen in this study. The rationale for choosing isolated tree stands is to account for the contributions of individual tree stands to soil in nutrient cycling, since their results were not affected by other tree canopies. In addition, the units of data collection are uniform and the canopies of isolated trees extend beyond the areas from which data were collected. Thus, isolated trees can be effectively compared with the rainforest.

This research investigated aspects of nutrient cycling and determined the contributions of nutrient elements to the rainforest soil by the isolated exotics. This is because studies on nutrient cycling provide insights into factors limiting tree growth and forest productivity (Hermansah *et al.*, 2002; Pragasan and Parthasarathy, 2005).

1.2 STATEMENT OF RESEARCH PROBLEM

It has been observed that once the rainforest is cleared for cultivation, the interrelationship between soil and plants is disrupted irrespective of whether field or tree crops are planted**.** Different trees in the tropical environments exert varying degrees of impact on the soil underneath (Ekanade, 2007). Therefore, isolated tree stands in the rainforest ecosystem of southern Nigeria should have exerted impacts on the soil physical and chemical properties.

The effects of the forest cover in intercepting rainfall and modifying the temperature and humidity at the ground surface is considerable. But, in the nutrient cycling process, the role of rainwash is significant in conveying nutrients to the soil (Chuyong *et al.*, 2004; Germer *et al.*, 2006; McJannet *et al.*, 2006). Hence, it is not surprising that in the rainforest ecosystem, the cycling of nutrient is very effective. At the time the plants are growing, there is a gradual deterioration in soil fertility resulting from the withdrawal of nutrients by plants from the soil. This however, has implication for the variation in the cycling of nutrients under different tree species.

Studies by Nwoboshi, (1985), Boettcher and Kaliz (1990), Weltzin and Coughenor (1990), Dunham (1991) and Ekanade (2003), which examined the effects of trees on soil nutrient characteristics revealed that different tree species exact varying effects on the soil underneath their stands. Some tree species do not significantly contribute to the improvement of soil organic matter, exchangeable cations, build-up of the extractable micronutrients – iron, copper, manganese and zinc under their canopies. The low organic matter concentration and nutrients in soil underneath the tree canopies is due possibly to frequent cultivation and burning of the vegetation prior to cultivation as opined by Nye and Greenland (1960). Indeed, the extent to which plant communities are determined by resource availability is central to ecosystem studies, but patterns of small-scale variation in resource availability are poorly known.

The effects of tree crowns in accumulating organic matter and nutrients under their canopies have been widely reported for forest ecosystems (Chuyong *et al.*, 2004; Pypker *et al.*, 2005). Also, the effects of canopy structure on stemflow and throughfall is necessary in evaluating the nutrients returned from individual tree stands through rainwash. Nutrients returned to the soil by tree stands are concentrated within the crown area where the return of nutrient elements through rainwash and litterfall are concentrated (Vitousek and Sanford, 1986).

Seasonal variations in nutrient flux have been reported by Muoghalu *et al.*, (1993), Muoghalu and Oakhumen (2000) and Chuyong *et al.* (2004) to have effects on nutrient availability in the soils under tree stands. Therefore, the need to ascertain the seasonal pattern of nutrient flux by different tree species is necessary. Such results are compared with those from the native rainforest. Although, trees in the rainforests are stratified, and stratification affects the results of nutrient returns through rainwash and litterfall for individual tree species evaluation, a comparative assessment between the isolated tree stands and the adjoining native rainforest is possible by collecting the required data from equal area. This brought the need to assess the cycling of nutrients under isolated tree stands so as to account for the contributions of individual tree species to the ecosystem in nutrient cycling.

Furthermore, comparative studies are important ways for understanding the nutrient cycle under trees (Vitousek and Sanford, 1986). The rate at which different plant species immobilize nutrients varies, and results of studies on the more economically important tree plants such as cocoa, teak, rubber, gmelina and oil palm cannot provide a rational basis to account for understanding nutrient cycling under every tree species, as different plant species exert varying effects on the soil. This emphasizes the need to examine the cycling of nutrients under isolated tree stands in the rainforest ecosystem.

Although several studies have been conducted on the effects of cultivated tree plants on soil properties in the rainforest ecosystems of West Africa, these studies as conducted by (Nye and Greenland, 1960; Ekanade, 1987; Adejuwon and Ekanade, 1988; Ekanade, 1988; Aweto and Iyanda, 2003, Akpokodje and Aweto, 2007) revealed that the levels of most soil nutrient properties were significantly lower under tree plants than under adjoining forests, but they did not investigate the contributions of nutrient elements to the soil by individual tree species in nutrient cycling. Although Adedeji (2008) examined the contributions of rubber trees to soil nutrient composition, the study was conducted on plantation ecosystem.

In response to the stated problems, this study examined the processes of nutrients return to the soil (as aspects of nutrient cycling) by isolated exotic tree stands, and compared the results with those of the adjoining rainforest. Such comparisons assist in the choice of the tree species which could be viable in the management of the soils in the rainforest ecosystem. The effects of the tree stands on the soils were also determined.

1.3 AIM AND OBJECTIVES OF THE STUDY

The aim of this study is to assess the aspects of nutrient cycling under isolated tree stands and determine the effects of individual tree species on rainforest soil characteristics. Therefore, the specific objectives of the study are to:

i. examine the variations in the biomass characteristics of the isolated tree stands and the adjoining rainforest;

ii. assess the differences in litter production amongst the isolated tree stands and ascertain the seasonal variations in litter production;

iii. investigate the relationships between litter production and nutrient returns to the soil through litterfall;

iv. determine the variations in the concentrations of nutrients in litterfall, stemflow and throughfall amongst the isolated tree stands;

v. evaluate the relative contributions of stemflow, throughfall and litterfall in returning nutrients to the soil in nutrient cycling; and

vi. assess the seasonal returns of nutrient elements to the soil through stemflow, throughfall and litterfall under the isolated exotic tree stands and the adjoining rainforest respectively.

1.4 RESEARCH QUESTIONS AND HYPOTHESES:

Research Questions: The following research questions were answered in this study:

i. Are soil characteristics under the different isolated tree species and those in the adjoining natural rainforest the same?

ii. Are there seasonal variations in litter production as well as the returns of nutrient elements to the soil through litterfall?

iii. Are there differences between the three tree species with respect to the concentrations of nutrients in stemflow, throughfall and incident rainfall?

iv. Are there differences in the nutrient composition of litterfall from the different isolated tree species and adjoining rainforest?

v. What is the contribution of stemflow, throughfall and litterfall to the soil in nutrient cycling?

vi. Are there seasonal variations in the returns of nutrient elements to the soil through stemflow and throughfall?

Hypotheses: The following hypotheses were tested:

i. There is a positive relationship between plant biomass characteristics and soil properties under the isolated tree stands and the adjoining rainforest.

ii. The concentrations and returns of nutrient elements to the soil through litterfall and rainwash vary amongst the isolated exotic tree stands and the adjoining rainforest.

iii. There is a significant difference in the returns of nutrient elements to the soil through litterfall, throughfall and stemflow.
iv. Nutrient elements returned to the soil through litterfall, throughfall and stemflow are positively correlated with soil nutrient elements underneath the tree stands.

1.5 JUSTIFICATIONS FOR THE RESEARCH

From the review of literature, it was observed that several studies have been conducted on nutrient cycling as well as the effect of trees on the rainforest soils. However, the studies conducted in the rainforest zone of southern Nigeria, did not investigate the nutrient contributions by individual tree species to the soil with respect to stemflow, throughfall and litterfall. This is because, where litterfall and rainwash were investigated, the studies were conducted in natural forests where tree canopies are not separated from one another, and could have effect in determining the returns of nutrient elements by individual tree stands. The effects of individual tree species on soil characteristics have also not been sufficiently investigated because the studies were mainly in plantations.

Studies on nutrient cycling in Nigeria’s rainforest were conducted in the drier part of the ecosystem. However, such studies did not attempt a comparative evaluation of litterfall and rainwash as essential aspects of nutrients return in a single study. This makes it difficult to compare the contributions of nutrient elements to the soil through litterfall, throughfall and stemflow. Although, study conducted by Adedeji (2008) examined the returns of nutrient elements to the soil through litterfall and rainwash, the study was conducted on plantation ecosystem. Therefore, this study was conducted on a wetter rainforest ecosystem. Litterfall and rainwash were observed to contribute to the improvement of the soil nutrient status characteristics under tree stands. Since minerals are immobilized in the standing crop of vegetation, increase in nutrients in the topsoil would depend on the balance between the loss of nutrients from the topsoil and the rate of mineral element replenishment in the topsoil (Aweto, 1978; Jordan, 1985).

This study is therefore necessary to provide quantitative data regarding tree-influence circle, soil-plant interrelationships, seasonal variations in nutrient flux by different tree species, and the contributions of litterfall and rainwash in nutrients return to the soil.

1.6 JUSTIFICATIONS FOR THE CHOICE OF STUDY AREA

Studies on nutrient cycling under isolated tree stands can be carried out in any part of the world where isolated tree stands are found. An approach to such studies would be to ensure that the tree stands are really isolated, with their canopies separated from other tree canopies. This is in order to effectively ascertain the contributions of individual tree stands to the soil in nutrient cycling. Also, such isolated tree stands should be free from the effects of fire, sweeping and other activities that can alter the natural process of nutrient cycling. Furthermore, seasonal variations in the returns of nutrient elements to the soil are essential in the processes of nutrient cycling.

These conditions necessitate the selection of an area which is homogenous in vegetation and climatic conditions. In southern Nigeria, the earlier studies on nutrient cycling were conducted in the drier rainforest and plantation ecosystems. The need to carry out a study of this kind in the wetter rainforest ecosystem becomes necessary.

However, these considerations led to the choice of Orogun as the study area; and it falls within the wetter rainforest zone, with homogenous vegetation and climatic conditions. The chosen isolated tree stands are commonly found in the study area because they are grown within the settlements and farm areas. In many parts of southern Nigeria where these tree stands are found, the impact of sweeping and burning were obviously seen to have affected the soil-plant interrelationships between the isolated tree stands and the soils underneath.

1.7 THE STUDY AREA

1.7.1 Location and Boundary:

The study was carried out in Orogun, Ughelli North Local Government Area of Delta State (Figs 1.2 and 1.3). The study area is located between latitude 5^0 20'N and 5^0 36'N, and also between longitude 5^0 30'E and 6^0 06'E. It is bordered to the North by Abraka in Ethiope East Local Government, to the South by Isoko North, to the West by

Kokori in Ethiope East, and to the East by Ukwuani and Ndokwa West Local Government Areas respectively.

1.7.2 Climate of the Study Area

Orogun falls within the humid sub-equatorial climate in Nigeria (Iloeje, 1965; Efe, 2006). The climate is dominated by two prevailing air masses: the tropical maritime air mass (MT) or south westerly monsoon air mass which is warm, moist and humid prevails throughout the wet season from March to October and the tropical continental air mass which prevails during the dry season. The tropical continental is dry and dusty and it is associated with harmattan season in the area (Efe, 2006). Orogun falls within the Niger Delta region which extends from the coast, and it falls within areas with annual rainfall of between 2000mm-4000mm. The distribution of rainfall pattern during the year is characterized by the double maxima regime; the two periods of maximum rainfalls being in July and September. Temperatures are relatively high throughout the year with slight seasonal variations. The mean annual temperature is about 31.5^0C while annual range is 2^0C (Efe 2006). The relative humidity of the atmosphere is usually high throughout the year owing to the dominance of the tropical maritime air mass. During the rainy season, the average relative humidity of the air is usually over 83%. The air is less humid during the dry season but the relative humidity of the air is still over 65% (Efe, 2006). The seasonal pattern of the area according to Richards (1953), Iloeje (1981), and Efe (2006) is as summarized below:

i. Long wet season: This starts from mid March to July. It is the season with heavy rainfall and high humidity.

ii. Short wet season: This follows the August break and occurs between September and October.

iii. The short dry season: This is the August break. It lasts for about two weeks in the month of August.

iv. Long dry season: This is the harmattan season between November and mid-March.

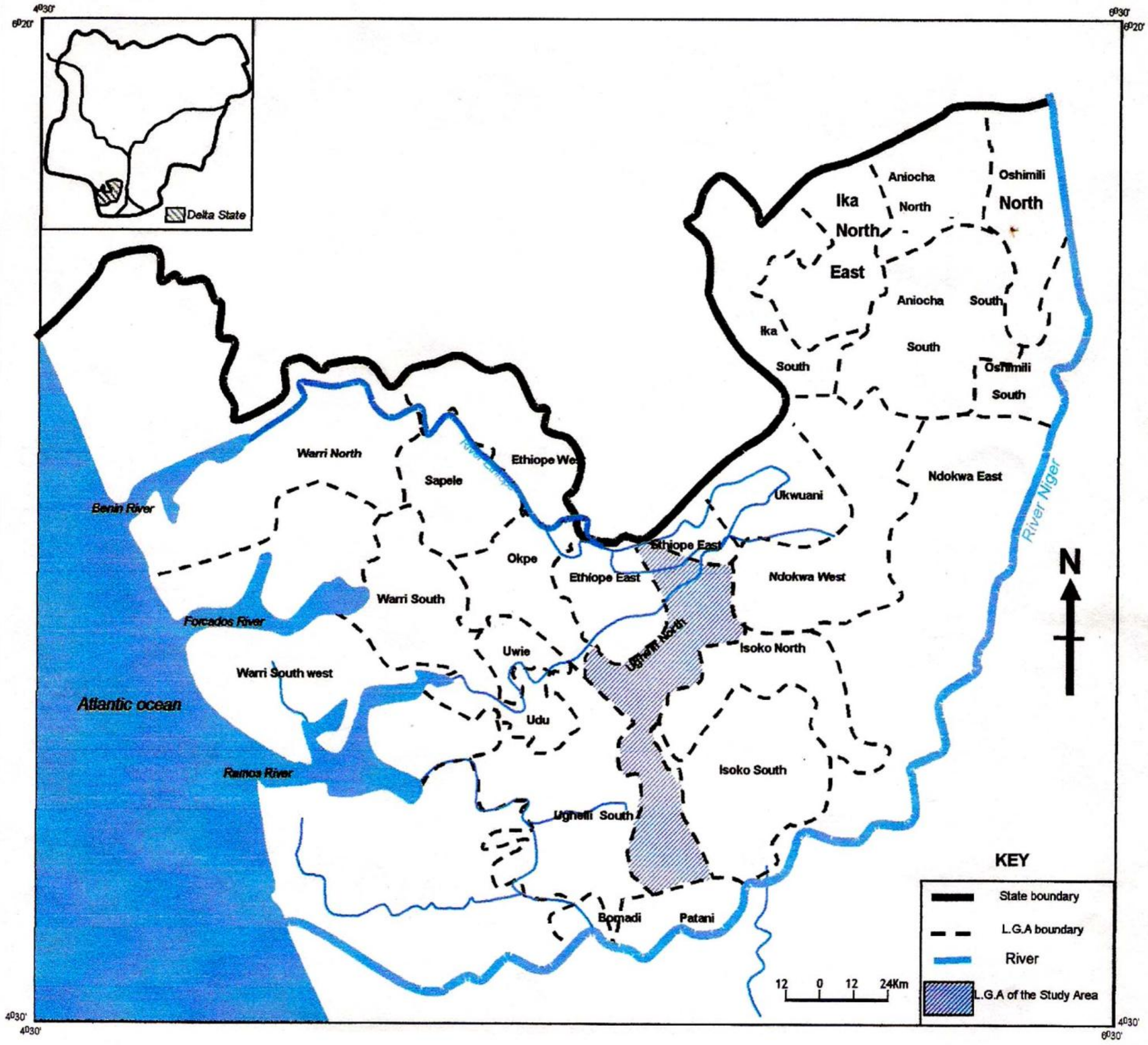


Fig. 1.1: Delta State Showing Ughelli North Local Government Area
Source: Ministry of Lands, Survey and Urban Development, Asaba (2004)

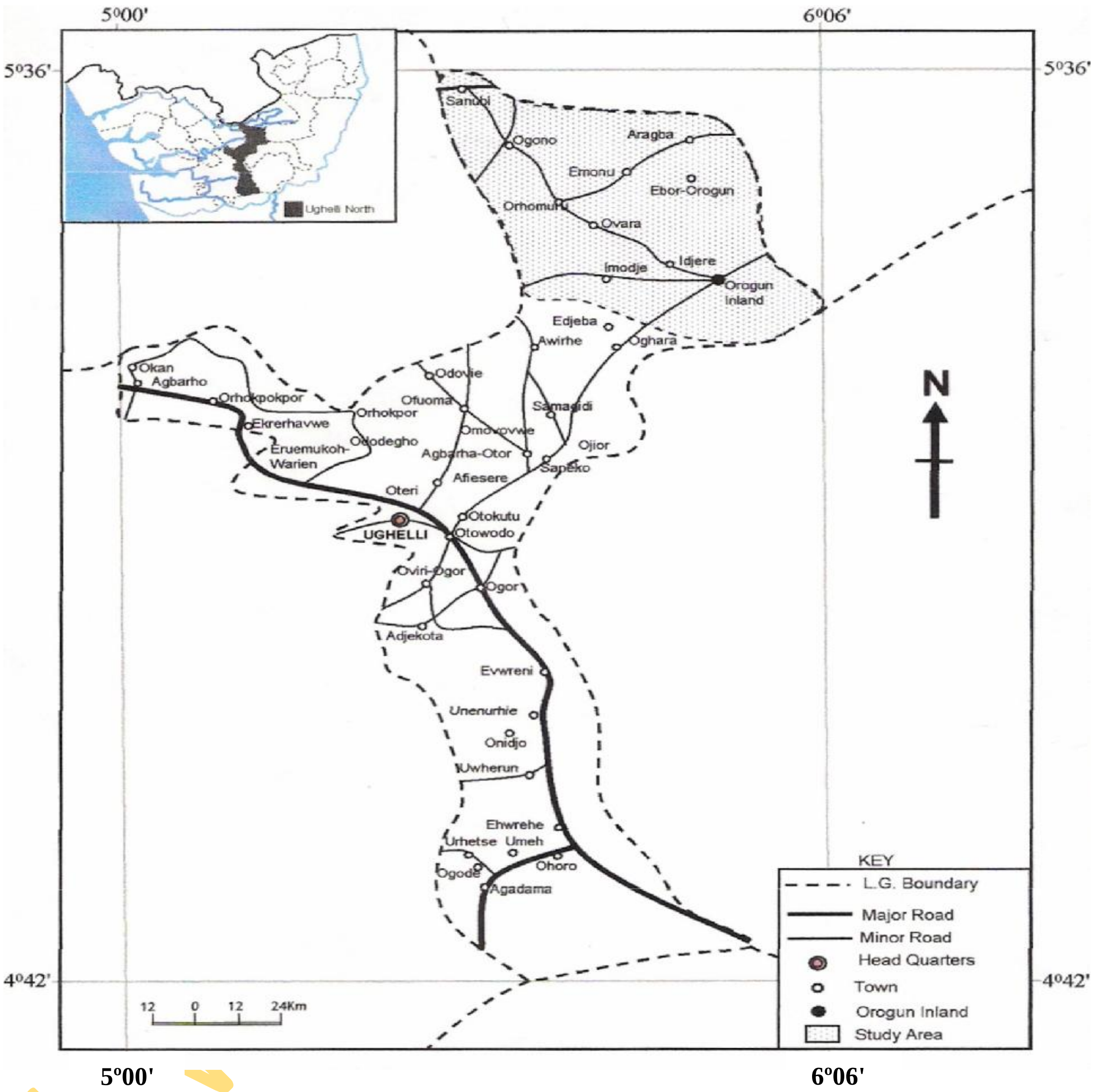


Fig. 1.2: Ughelli North L.G.A. Showing the Study Area
Source: Ministry of Lands, Survey and Urban Development, Asaba

1.7.3 Vegetation of the Study Area

The vegetation of this study area is discussed under: The rainforest, freshwater swamp and derived savanna / grassland landscapes.

i. The Rainforest Vegetation

The natural vegetation is lowland rainforest of the moist evergreen forest type. Owing to the prevalent agricultural practice of shifting cultivation, most of the original forest has been destroyed and the landscape is now dominated by a mosaic of different stages of farms and succession communities (Aweto, 1981). The originally contiguous luxuriant forests are now confined to sacred places and feature as forest relics.

The rainforest vegetation depends on the total annual rainfall and its distribution throughout the year. According to Vickery (1984), rainforest is the most species diverse of any vegetation. Plants growing in such habitat receive continuous water and warmth, while deficiency of nutrients is unlikely to occur due to rapid recycling (see fig. 1.1 for the main features of nutrient cycling in tropical rainforest ecosystems).

The only limiting factor is light, and it applies only to plants of the lower canopies. The mature forest is well-developed physiognomically with three identifiable tree layers, a shrub layer and an herb layer on the forest floor. Trees of the top layer reach 40 meters or more, while those of the lowest layer average only 10 meters. The crowns are small; their shapes depend on the layer which they belong to. The shrub layer of the forest consists of a mixture of true shrubs and saplings which are unable to mature due to lack of light, while the herb consists entirely of shade loving plants (sciophytes). Lianas and epiphytes are scattered throughout the main vegetation layers. They have solved their light requirement problems by climbing over other vegetation (lianas) or growing on the branches or trunks of trees (epiphytes). Among the tree species occurring in the forest of the study area are *Piptadeniastrum africanum*, *Ceiba pentandra*, *Albizia adianthifolia, Terminalia superba, Alstonia boonei, Milicia excelsa, Ricinodendron heudelotii, Musanga cecropioides* and *Antiaris toxicaria*.

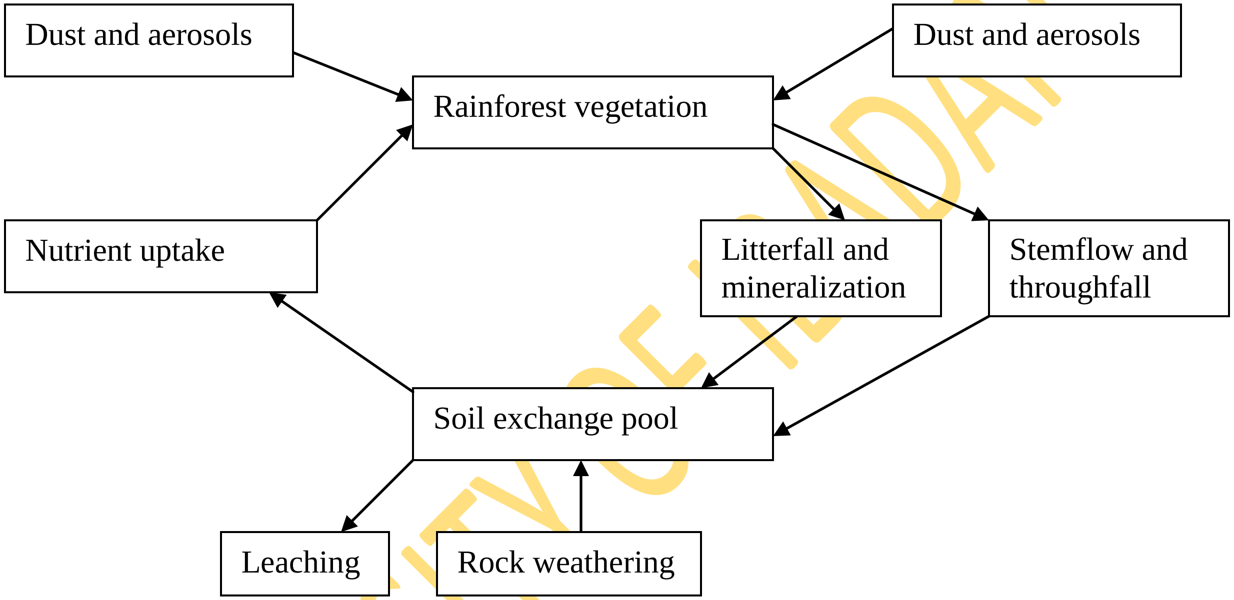


Fig.1.3: Main Features of Nutrient Cycling in Tropical Rainforests (after Aweto, 2001)

ii. The Fresh-Water Swamp Vegetation

The freshwater swamp forests are found around the bodies of water in the study area. This vegetation is characterized by two tree strata - the upper and lower strata. Trees in the upper strata can reach a height of 40-45metres. They include the wide expanse of riparian vegetation found within the study area. The most common species of plants found in this ecosystem is the Raffia palm - *Raphia hookeri* and *R. vinifera*, from which a sweet type of wine that goes by the same name is tapped.

iii. The Grassland Vegetation.

The grassland vegetation in this study area are those grassland areas found within the rainforest belt of the region. These grasslands feature in disjoint distribution form, and are uniquely different from those of the savannah ecosystems in Northern Nigeria. This vegetation includes the different grasslands found in areas such as Ugono, Aragba, Erhobaro and Idjerhe.

The grassland areas are mainly dominated by grasses. They do not contain tall trees, possibly due to geographical isolation within the forest, flooding and bush fire. However, small trees feature scantily within some of the grasslands. The dominant species of grasses found in this region include *Panicum maximum, Imperata cylindrica and Hyperrhenia spp.* The grasses have durable roots which remain underground after the tops have been burnt during the dry season, and sprout again with the onset of the early rains in the year.

1.7.4 Geology and Landscape of the Study Area

The study area which falls within the Niger Delta region consists mainly of sedimentary formations deposited in three cycles of marine transgressions. According to Odemerho (2007), the surficial geology comprises the Sombreiro-Warri Deltaic plain formation. The Sombreiro-Warri formation underlies much of the Deltaic plain, an area also referred to as the “Urhobo plains” (Aweto, 1987). The lithologies of these surficial materials show evidence of a variety of depositional environments that include deltaic, fluvial and ages that range from Miocene through Pleistocene to the recent (Wright, 1985). At the end of the Pleistocene Ice Age, the gradual rise in sea level and groundwater table produced the requisite hydromorphic environment for the podzolization of the base-deficient and deeply weathered sand-rich deltaic plain alluvium deposits to form the "white sand", especially in the swamps and abandoned river floodplains where savanna type of vegetation predominates (Aweto, 1987; Thomas, 1994).

The processes of formation, transport and deposition of materials that accumulate as sediment which eventually form sedimentary rocks within this environment are here presented. The evolution of the delta is controlled by pre-and synsedimentary tectonics as described by Evamy *et al*. (1978), Stacher (1995) and Reijers (2011). The delta growth is summarized below: The shape of the cretaceous coast line gradually changed with the growth of the Niger Delta. A bulge developed due to delta growth. This changing coastline interacted with the palaeo-circulation pattern and controlled the extent of incursions of the sea. Other factors that controlled the growth of the delta are climatic variations and the proximity and nature of sediment source areas.

Within the Niger Delta environment, one petroleum system—the Tertiary Niger Delta (Akata-Agbada) petroleum system is identified (Stacher, 1995; Reijers, *et al.*, 1997; Reijers, 2011.). The delta formed at the site of a rift triple junction related to the opening of the southern Atlantic starting in the Late Jurassic and continuing into the Cretaceous. According to Reijers (2011), the delta proper began developing in the Eocene, accumulating sediments that are now over 10 kilometers thick. The primary source rock is the upper Akata Formation, the marine-shale facies of the delta, with possibly contribution from interbedded marine shale of the lower-most Agbada Formation (the reservoir rock). Oil is produced from sandstone facies within the Agbada Formation, however, turbidite sand in the upper Akata Formation is a potential target in deep water offshore and possibly beneath currently producing intervals onshore.

Delta subsidence and progradation rates followed those of megasequence (Udo, *et al.,* 1988). In the active Greater Ughelli depobelt, the late Eocene shoreface deposits grade down dip into pro-delta/open-marine deposits. Shoreface sediments formed simultaneously in the active Greater Ughelli depobelt. Within this depobelt, up to five higher-order sequences reflect phases of prograding barrier complexes. Delta subsidence remained stable, but a sudden early Miocene sea-level drop was followed by irregular progradation pulses (8-15km/ma) coinciding with an increased sediment supply and delta-lobe switching. This may have triggered renewed incision of the Opuama channel at 21.8ma (Udo and Ekweozor, 1988) and associated basin-floor sand deposition within the open-marine part of the active Greater Ughelli depobelt. These events alternated with clay in-filling of the channels during intermediate and high sea-level stands.

The Akata formation at the base of the delta is of marine origin and is composed of thick shale sequences (potential source rock), turbidite sand (potential reservoirs in deep water), and minor amounts of clay and silt. Beginning in the Paleocene and through the recent, the Akata formation formed during low stands when terrestrial organic matter and clays were transported to deep water areas characterized by low energy conditions and oxygen deficiency (Stacher, 1995). The formation underlies the entire delta, and is typically over-pressured. Turbidity currents likely deposited deep sea fan sands within the upper Akata formation during development of the delta (Burke, 1972).

Deposition of the overlying Agbada formation, the major petroleum-bearing unit, began in the Eocene and continues into the recent. The formation consists of paralic siliciclastics over 3700 meters thick and represents the actual deltaic portion of the sequence. The clastics accumulated in delta-front, delta-topset, and fluvio-deltaic environments. In the lower Agbada formation, shale and sandstone beds were deposited in equal proportions; however, the upper portion is mostly sand with only minor shale interbeds. The Agbada formation is overlain by the third formation, the Benin formation, a continental latest Eocene to recent deposit of alluvial and upper coastal plain sands that are up to 2000m thick (Avbovbo, 1978).

The landscape is a low-lying deltaic plain interspersed with waterlogged depressions and freshwater swamps. With an elevation of less than 25 meters above sea level, the area is liable to annual flooding that spreads highly fertile alluvium on the region.

1.7.5 Soils of the Study Area

The soils in this study area are of the Sombreiro-Warri Deltaic plain types, which are classified as hydromorphic and alluvial soils (Mogborukor, 2007). These soils are mainly derived from coastal deposits which consist of well drained sandy loam over coarse sandy clay loam subsoil. The soils contain essential characteristics which support the growth and development of rainforest trees as well as cultivated plantation tree plants such as mango, almond, alvocado pear, guava, rubber and oil palm.

However, following the USDA soil classification system (Soil survey staff, 1994), the oxisols is one of the major soil orders within the study area. This soil order depicts the characteristics of the soils in Orogun. According to Soil survey staff (2003), the bedrock of oxisol is weathered and consequently depleted in minerals and nutrients. Oxisols have a high aluminum and iron oxide content, and low silica content. The profiles of oxisols contain mixtures of quartz, kaolin, iron and aluminum oxides, and organic matter. The abundance of iron and aluminum oxides found in the soils, result from chemical weathering and leaching. Many oxisols contain laterite layers because of a seasonally fluctuating water table. Thus, when the forests overlying such oxisols are cut down, the soil becomes much drier and eroded, and this often leads to laterization. This will not happen if the surface is covered with trees and vegetation. Because laterite is impermeable, rain will run off quickly, leading to erosion and flooding. Oxisols depend mostly on the quality and amount of organic matter for retention of cation. Without fertilizers, they can support extensive agriculture only under shifting cultivation or with tree crops that protect the soil.

The soils in this study area are typically nutrient-poor owing to leaching. Any nutrient in the soil would be swiftly leached away by the heavy rainfall. Although the soils in the lowland rainforest ecosystems are said to be nutrient-poor, the ecosystems are known to be very productive. The high productivity does not require soils to contain large nutrient reserves (Stark and Jordan, 1978). What seems to happen in this ecosystem is that any litter that falls to the ground is rapidly decomposed. The nutrients thus released into the soil are then rapidly taken up by the surface roots of trees and other plants before being leached from the soil. What makes humid rainforest ecosystems productive, according to Jordan (1985), Sanford and Cuevas (1996), is the combination of high temperature, light and rainfall year-round, which support effective litter decomposition and therefore the return of nutrient elements to the soil. However, not all the soils in the study area are so poor. Greenland and Kowal (1960) observed that some rainforest trees grow on nutrient-rich flood plain soils.

1.7.6 Economic Activities and Land Use

The land area of the study area provides necessary physical environment for farming. The farming practices include arable farming, tree crop production and animal husbandry. Tree crops are cultivated as plantation of monocultural crops. Many of these tree crops are also planted to produce fruits and shade within the settlement, schools and surrounding bushes. Some of these tree crops are grown in isolated stands since they are not cultivated as plantation. However, some of the tree plants feature in the market gardens.

Bush fallowing is currently the major system of crop production in many tropical countries. It involves the use of natural regeneration of fallow vegetation to restore soil fertility after cultivation (Richards, 1953; Nye and Greenland, 1960). Farming in this study area is typically at subsistence level, although some farming also takes place especially for tree crop production such as oil palm and rubber. Food crops grown include cassava, yam, maize, pepper, okra and vegetables. Inland water fishing takes place in the different rivers. While commercial fish farming is carried out at different scales of production within the region.

1.8 DEFINITION OF TERMS

Litterfall: Litterfall refers to the leaves, twigs and small wood that fall to the forest floor, which return nutrient elements to the soil. In mature rainforest ecosystems, litterfall also includes the fall of branches and stems (Nye, 1960; Edwards and Grubb, 1982; Vitousek, 1984). Tree litter will unquestionably lead to accumulation of organic matter under and near the trees (Vetaas, 1992).

Litter production: Litter production is the weight of dead materials of plant origin that reaches unit area of the soil surface within a standard period of time (Chapman, 1976). All materials that die do not immediately fall to the ground.

Rainwash: This refers to the washing of nutrients from the leaves and stems of plants by rainfall. Dust accumulation on leaves and branches, transported to the soil by throughfall and stemflow is suggested as an important input of mineral nutrients and nitrogen (Nye and Greenland, 1960; Parker, 1983; Escudero *et al.*, 1985; Newson, 1997; Ward and Robinson, 2000). In the rainforest ecosystems, tree canopies intercept rainfall and redistribute the water to the atmosphere by evaporation and to the ground by throughfall and stemflow.

Stemflow: This refers to that precipitation reaching the ground by running down the stems and boles of trees (Parker, 1983). Stemflow contains nutrient elements, and therefore is a medium through which nutrients are returned to the soil from the plants in nutrient cycling (Chapman, 1976).

Throughfall: Hamilton and Rowe (1949), defined throughfall as that part of precipitation to reach the ground directly through gaps in the canopy or as drip from leaves and stems.

Rainforest Ecosystem: A thick evergreen tropical forest found in areas of heavy rainfall and containing trees with broad leaves that form a continuous canopy which feature in strata (Vickery, 1984).

Adjoining rainforest area: These are natural rainforest areas that are closest to the isolated tree stands. Most of these forests are relics of the originally contiguous rainforest in the region.

Savanna/grassland areas: This refers to the resultant areas covered by grasses and short trees in the rainforest ecosystem

Isolated tree stands: This refers to tree stands which their canopies are separated from other tree canopies.

Tree crown area: This is the area underneath tree stands occupied by a perpendicular projection of the crowns of individuals of the tree species under consideration.

Basal area: This refers to the measurement of the area covered by tree trunks at ground level.

Diameter at Breast Height (DBH): This refers to the diameter measurement of tree trunks taken at an arbitrary height (4ft 3in or 1.3m), and called breast height.

Nutrient Cycling: This is the process by which plants absorb nutrients from the soil, and in turn, return nutrient elements to the soil through litterfall and rainwash.

Porosity: This refers to the percentage of a material's total volume that is taken up by pores. This "empty" space has the ability to hold air and water that seeps down from the land surface. Material with good porosity can be called "porous". Porosity depends on the size, shape, and mixture of grains and particles that compose soil and rock.

Permeability: Permeability is the measure of how easily water flows through soil or rocks. It depends on the size of the pore space and how well connected they are to one another.

Rainfall events: This refers to a measurable rainfall amount (0.254mm) followed by a 24 hour period of non-rainfall. This is capable of generating a higher volume of stemflow. The difference between a rain shower and rain event is magnitude. Rain showers generate only small volumes of stemflow (Levia, 2003).

CHAPTER TWO

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 INTRODUCTION

The interrelationships between the elements of soil and those of the plants in rainforest ecosystem were studied within the framework of integrated concepts of "tree influence circle" and "nutrient cycling". However, the review of related literature was based on the processes of nutrient cycling, plant-soil relationship, and the effects of trees on soil properties.

2.2 CONCEPTUAL FRAMEWORK

This study was conducted using the framework of "**tree influence circle**" and "**nutrient cycling**" concepts. The concepts were so applied because they well explained the interrelationships between plant and soil in the rainforest ecosystem.

2.2.1 The Concept of Tree Influence Circle

The concept of tree influence circle has been greatly applied in the study of soils under trees. Some studies as conducted by Ekanade (1985; 1989), Boettcher and Kalisz (1990), Aweto and Moleele (2005), Aweto and Akpokodje (2007), applied the concept as "single-tree influence circle". These studies examined the influence of single tree species on soil properties. In some other studies as conducted by Aborishade and Aweto (1990), Ekanade (1990), Dunham (1991), Aweto and Dikinya (2003), the concept was applied to examine the influence of two or more tree species on soil properties. Generally, the concept of tree influence circle emphasizes how trees exert influence on their immediate environment, especially on the soils underneath. The knowledge of the effects of trees on the soil is essential for evaluating the role of trees in rainforest ecosystems, and the desirability or otherwise of retaining tree plants in the ecosystems (Ekanade, 2007). The need to evaluate the effect of trees on soil properties has become necessary. As observed from the different studies on tree influence circle, the effects of trees on the soil will vary depending on the type of tree in question. Some tree species may accumulate nutrients in their standing biomass and the rate of nutrient storage in their biomass may be greater than the rate of storage in the soil. They generally tend to immobilize nutrients faster than recycling them to the top soil (Nye and Greenland, 1960; Aweto, 1987).

Trees absorb nutrients from the soil. The nutrients are mobilized in the standing biomass and then recycled back into the topsoil mainly through litterfall, droppings from birds, and in other cases, through rainwash. Through these processes of nutrient return, trees help to accumulate organic matter and nutrients in the rainforest soil (Wood *et al*, 2006). The bulk of the litter is concentrated under the tree canopies. The tree canopies intercept solar energy thereby reducing soil temperature, and this may lead to reduction of organic matter composition in the soil (Nye and Greenland, 1960).

Soil nutrient decline usually sets in once there is loss of biodiversity following the conversion of natural forest into monocultural plantation of tree species due to a destabilization of the nutrient cycle (Aweto and Ekiugbo, 1994). Therefore, the conversion of natural rainforest into the cultivation of isolated tree plants should have exerted influence on the soil, in the course of their interactions as component parts of the ecosystem. This interaction can further be explained by the concept of nutrient cycling.

2.2.2 The Concept of Nutrient Cycling

This concept is based on the interrelationships between plants and soil in an ecosystem. Plants absorb moisture and nutrients from the soil, which are in turn used up by plants for growth and production (Nye and Greenland, 1960). However, plants return nutrients back to the soil through litterfall and rainwash (Pragasan and Parthasarathy, 2005). The role of soil flora and fauna in the decomposition process is important. They help to decompose wood, bark and dead leaves into humus and eventually breakdown of humus so formed into carbon (IV) oxide, water and nutrient matter. In the nutrient cycling process, the role of rainwash from the leaves and stem of plants is also significant in conveying nutrients to the soil (Chuyong *et al.*, 2004). Therefore under the rainforest ecosystems, the plant-soil system is a complex ecological entity. Whenever the forest is cleared for cultivation, the plant-soil equilibrium is disrupted, which eventually leads to a gradual deterioration in soil fertility resulting from the withdrawal of nutrients by plants and the exposure of the soil to agents of erosion. Erosion can lead to loss of organic matter and mineral nutrients, an increase in acidity, a loss of clay particles and a deterioration in structure as the soil becomes more compacted (Jeje *et al.*, 1982). There is therefore a link between the soil and plant cover regarding cycling of nutrients and moisture. Hence, cycling of matter or nutrient cycling is an important way in which soils and plants relate (Muoghalu and Oakhumen, 2000; Pypker *et al.*, 2005; Adedeji, 2008).

Therefore, the complex interrelationship between the elements of soil and those of the plants in rainforest ecosystem suggest that a more meaningful and realistic approach to the study of nutrient cycling under isolated tree stands has to be within the framework of integrated concepts of **"tree influence circle"** and **"nutrient cycling".** The applications and studies regarding these two concepts are well discussed in the review of literature section under the "plant-soil system model" and "the effects of plants on soil properties".

2.3 LITERATURE REVIEW

A review of the literature related to this research was made to cover different areas under subtopics such as: the processes of nutrient cycling, plant-soil relationship and the effect of trees on soil properties.

2.3.1 The Processes of Nutrient Cycling

The cycling of nutrients between the soil and vegetation in terrestrial ecosystem occurs via the following processes.

a. Uptake of Nutrients from the Soil by Plants
b. Removal of Nutrients From plants and Return to the Soil
c. Decomposition and Mineralization of Litter

Fig. 2.1 shows the processes of nutrient cycling in forest ecosystem.

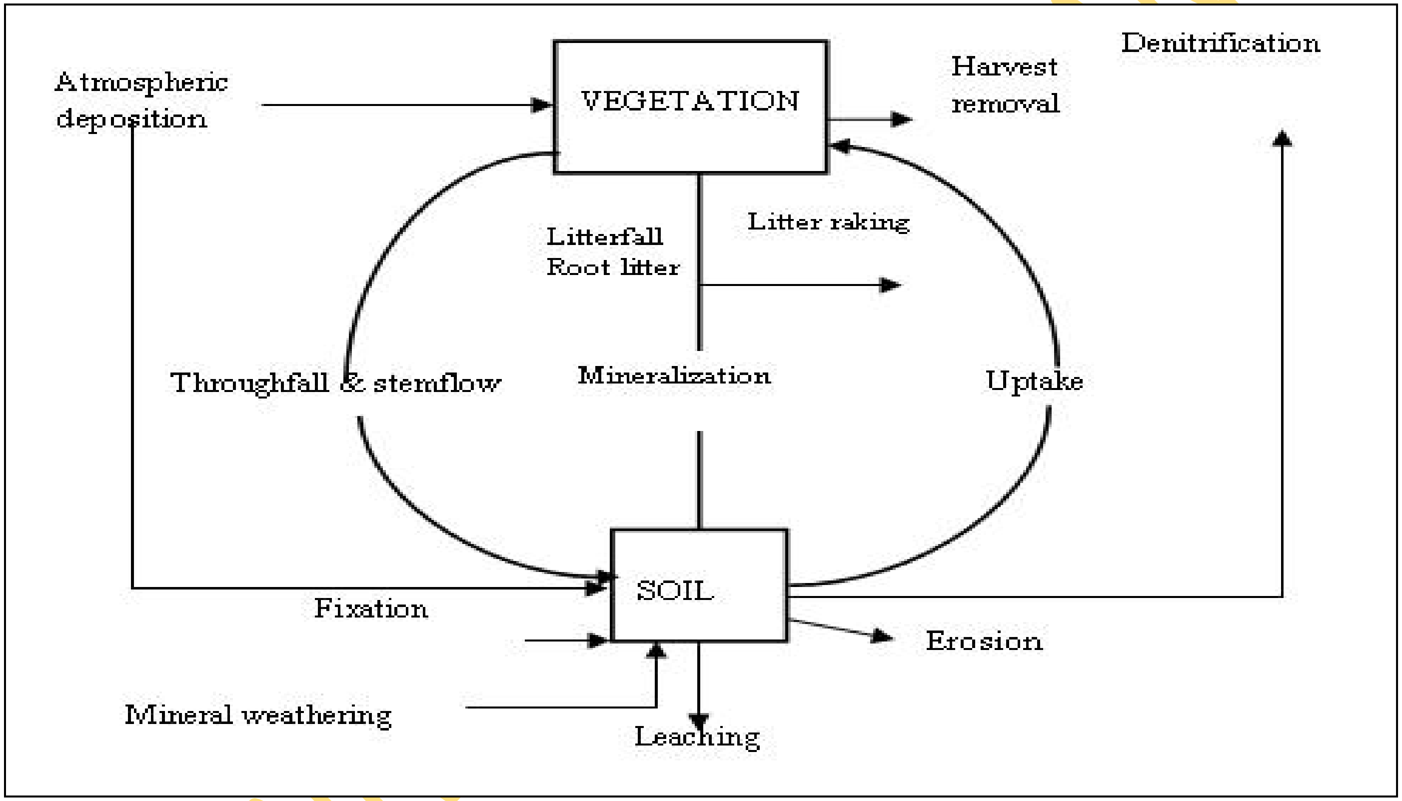


Fig 2.1: Schematic presentation of nutrient cycling processes in forest ecosystems (modified after Aweto, 2001)

a. Uptake of Nutrients from the Soil by Plants

Trees in the rainforest ecosystems have a number of features which help them to obtain nutrients. They produce a large root biomass which is concentrated near the surface. These roots seem to be very effective in absorbing moisture and nutrients (Stark and Jordan, 1978). For example, when Stark and Jordan (1978) added radioactive calcium and phosphorus to the soil surface of lowland rainforest, they found that 99.9% of the radioactivity ended up in roots; only 0.1% was lost by leaching.

Nutrients absorbed by plants are used up for their growth and production in the ecosystems. According to Stark and Jordan (1978), Vitousek and Matson (1988), Poss and Saragoni (1992), minerals in the soil are almost immediately taken up by a thick mat of plant roots and root-like fungi. Many of them form symbiotic relationships with plant roots. They supply the plants with minerals and water, and the plants return sugars to the fungi. The association between plant and the fungus is so close that in some cases, the root/fungal mat is so thick that there is direct nutrient cycling – nutrients move from dead organic matter into the roots without entering the soil.

Intense mycotrophism is seen in these roots (Vitousek, 1984; Sanford and Cuevas, 1996). The hyphal mass functions as an absorptive wad in the surface soils. The rainforest ecosystems appear to depend upon the ability of this layer to capture phosphorus mobilized from decomposition and thus preempt sorption in the subsoil. According to Nwoboshi (1975), the zones of fine-root concentration also coincide with the zone of earthworm casting. The uppermost parts of the soils are thus markedly different from the remainder of the profile, and appear critical for the functioning of the nutrient cycle.

The total rate of nutrient uptake (in excess of any that may be returned back to the soil through the roots) is equal to the increase in storage in the vegetation plus the amount removal from the vegetation (Jordan, 1985).

Since mineral elements are being immobilized in the standing crop of vegetation, increase in nutrients in the topsoil would depend on the balance between the loss of nutrients from the top-soils, and the rate of mineral element replenishment in the topsoil (Nye, 1960; John, 1973; Aweto, 1978; Jordan, 1985). The nutrient elements immobilized in the standing crop of fallow vegetation are a part of the total nutrient capital that will be available to crops during the cropping period (Nye and Greenland, 1960).

b. Removal of Nutrients from plants and Returns to the Soil

The removal of nutrients from vegetation and their return to the soil can be discussed under litterfall (litter production and nutrient content), rain wash (throughfall and stemflow), and mineralization of litter (Nye and Greenland, 1960; Chapman, 1976; Edwards and Grubb, 1977).

i. Litterfall

Trees in the rainforest ecosystems help to maintain soil fertility by adding litter to the soil and improving soil physical status. The nutrient content of the litter has generally been taken as a measure of the annual nutrient turnover (Nye and Greenland, 1960). However, litter consists only of leaves, twigs and small wood. In mature rainforest ecosystems, litter also includes the fall of branches and stems (Nye, 1960; Edwards and Grubb, 1982; Vitousek, 1984). Tree litter will unquestionably lead to accumulation of organic matter under and near the trees (Vetaas, 1992). The actual nutrient enrichment will depend on the nutrient content of the leaves and fruits before abscission. The activities of the soil fauna are of great significance. Through this activity, litter and other organic materials are incorporated into the soil, and soil conditions are improved, both physically and chemically. This activity has a shorter duration under the rainforest ecosystems in West Africa. The litter in the sub-canopy areas alters the physical properties of the surface soil. This may reduce the soil temperature and evaporation, and improve infiltration which subsequently increases sub-canopy moisture content (Tiedemann and Klemmedson, 1977; Joffre and Rambal, 1988).

Litter production is the weight of dead materials (of both plant and animal origins) that reaches unit area of the soil surface within a standard period of time (Chapman, 1976). All materials that die do not immediately fall to the ground. The production of litter by the above ground vegetation represents a major component of the net primary production, and its measurement is important whether it be in relation to primary production, or for consideration of other relationships within the ecosystem (Bray and Gorham, 1964; Sanford and Cuevas, 1996).

In a moist rainforest ecosystem in Ghana, John (1973) measured monthly fall of small litter in traps over 26months, wood litter once over 6 months, as well as dry weight of ground litter and its rate of disappearance. Litterfall was greatest from January to early March, with a small peak in leaf fall also from September to early December; the major peak corresponds to the driest part of the year. About 77% of the total annual fall of 966g/m^2 was leaf materials. No significant differences were found between forest growing on two different soil types, and little difference between two years. Litter decay times ranged between 0.25 and 9.0 years, with leaf litter disappearing nearly three times s fast as twigs. Net dry matter production was estimated roughly as 2200-2500g/m^2/year.

Lowland rainforest ecosystems generally have more nitrogen and lower dry mass/nitrogen ratios in litterfall than nitrogen return in montane rainforest ecosystems (Vitousek, 1984; Jordan, 1985; Sanford and Cuevas, 1996). Many rainforest ecosystems in West Africa have little phosphorus return and very high dry matter/phosphorus ratios in litterfall (Nye, 1960; John, 1973). In a study by Sanford and Cuevas (1996), fine litterfall was predicted from climate, and the residuals of this regression were positively correlated with phosphorus but not nitrogen concentration in litterfall. Fine litterfall was also significantly correlated with phosphorus concentration in moist and wet lowland rainforest ecosystems. This suggests that phosphorus but not nitrogen availability limits litterfall in a substantial subset of intact rainforest ecosystems.

ii. Rainwash (throughfall and stemflow)

The washing of nutrients from the leaves and stems of plants by rainfall is an important source of nutrient return to the soil underneath the plants (Nye and Greenland, 1960; Newson, 1997; Ward and Robinson, 2000). Dust accumulation on leaves and branches, transported to the soil by throughfall and stemflow is suggested as an important input of mineral nutrients and nitrogen (Parker, 1983; Escudero *et al.*, 1985). In the rainforest ecosystems, tree canopies intercept rainfall and redistribute the water to the atmosphere by evaporation and to the ground by throughfall and stemflow. The amount of water lost by interception is positively correlated with tree size (Pressland, 1973).

Increasing tree size may also decrease throughfall and stemflow, and the value of rain wash in the rainforest ecosystems depends on the frequency and intensity of the rainfall (Pressland, 1973; 1976).

The amount and composition of nutrient elements in rain falling beneath a moist rainforest ecosystem in Ghana were measured continuously throughout one year by (Nye, 1960). From this study, 16% of annual rainfall was intercepted by the canopy and evaporated before it reached the ground. Very large amounts of potassium, as well as significant amounts of phosphorus and magnesium were washed down; while only a little nitrogen and calcium were washed out of the canopy by rain, with HCO_3 – as the anion. Studies by Hansen (1994), Soulsby and Reynolds (1994) also reported low amounts of nitrogen and calcium washed from tree canopies; as well as little Na, Cl or SO_4 leached as leaf drips. However, the chemistry of effective precipitation (i.e. that reaching the soil surface) is determined by the pathway taken through the vegetation canopy (i.e. throughfall and stemflow).

Throughfall: Hamilton and Rowe (1949), defined throughfall as that part of precipitation that reaches the ground directly through gaps in the canopy or as drip from leaves and stems. Throughfall is positively correlated with precipitation and thus low rainfall events may be effectively intercepted (Pressland, 1973; Weltzin and Coughenor, 1990). In the rainforest ecosystems, there may be substantial changes in solute chemistry as the water interacts with the canopy due to leaching from vegetation, biotic uptake and the washing off of dry deposited elements (Parker, 1983). Throughfall is dependent upon the spaces in the vegetation canopy (Ward and Robinson, 2000). It is the drips from twigs, branches and leaves, and is concentrated near crown of the tree or vegetation (Newson, 1997).

Under rainforest ecosystems, there are three kinds of spatial variation in throughfall, and all the sources of variations together with any topographic variation in a site, must be accounted for when sampling (Chapman, 1976). The variations are:

- Systematic variation below individual plants.
- Variations within the general pattern of the individual plants caused by differences in crown size, height etc.
- Gaps in the canopy through which precipitation penetrates directly to the ground.

Stemflow: This refers to that precipitation reaching the ground by running down the stems and boles of trees (Parker, 1983). This stemflow contain nutrient elements, and therefore is a medium through which nutrients are returned to the soil from the plants in nutrient cycling (Chapman, 1976). Thus in the rainforest ecosystems, stemflow generally has much higher solute concentrations than throughfall due to the longer period of contact with the vegetation. The extent of nutrient removal from plants by stemflow varies widely according to the treatment of the plants contained in the rainforest ecosystem.

In general, stemflow and throughfall primarily improve the infiltration rate resulting in deeper wetting, and subsequently leaving the surface soil unsaturated, and thus it may only benefit the trees in the ecosystems (Walker and Noy-Meir, 1982).

c. Mineralization of Litter

The mineralization and release of plant nutrients within the litter layer in the rainforest ecosystems are processes in which the soil fauna plays an important part. In terms of mineralization, the microbial activity will immobilize the nitrogen into microbial biomass (Vetaas, 1992). When the litter under rainforest ecosystem has built up to its maximum level, the rate of mineralization clearly equals the rate of addition. However, this level is rapidly attained due to the associated high temperature and rainfall in the ecosystems. Possible increase in storage of nutrients in the form of litter need hardly be taken into account (Greenland and Nye, 1960). The maximum level of individual nutrient stored in the litter will be even more rapidly attained. The mineralization and release of plant nutrients within the litter layer are processes in which the soil fauna play an important part. In terms of mineralization, the microbial activity will immobilize the nitrogen into microbial biomass (Vetaas, 1992).

2.3.2 The Plant-Soil Relationships

Soils and plants are closely related and they are associated with one another. The circularly causal interrelationship between soils and plants has long been applied in geographical researches in Biogeography (Areola and Aweto, 1979). The soils in the environment support the growth of plants. These plants get their moisture and nutrients from the soil. As the plants develop, they shed their leaves. These leaves that fall together with some dead branches decay to enhance the nutrients of the soils. The plants utilize the moisture and nutrients for their growth and development. When the plants die, they decay to enhance the nutrients of the soils again. There is therefore a link between the soils and plant cover regarding cycling of nutrients and moisture. Cycling of matter or nutrient cycling is an important way in which soils and plants relate.

The role of soil flora and fauna in the decomposition process is important. They help to decompose wood, bark and dead leaves into humus and eventually breakdown of humus so formed into carbon (IV) oxide, water and nutrient matter. In the nutrient cycling process, the role of rainwash from the leaves and stem is also significant in conveying nutrients to the soil (Chapman, 1976). This cycle is continuous until the plants die. Therefore, under the tropical rainforest, the plant-soil system is an extremely complete, resilient and stable ecological entity, strongly buffered against change induced by environmental effects, notably the seasonal and diurnal climatic changes (Moss, 1969).

The plant and the soil beneath it are interrelated and exert reciprocal effects on one another (Aweto, 1978). However, the complex interrelationship between the elements of soil and those of the plants in an ecosystem suggest that a more meaningful and realistic approach to the study of plant-soil relationship has to be within the framework of an integrated plant-soil system model (Aweto, 1978; Ekanade, 2007).

The nutrient cycle between soil and forest fallow (fig 2.3) shows that plants and soil underneath are interrelated. However, in recognition of the need for the plant-soil system approach, Moss (1969) has argued against the practice of examining soil and vegetation as separate entities. This is because they operate as two separate but strongly dependent open systems. To neglect soil is to eliminate the part of the plant-soil system which will remain when the vegetation has been removed for cultivation; to neglect the vegetation is to make it impossible to evaluate, or even recognize, those soil properties which influence and are influenced by it. In other words, neither the changes which take place in the soil under the isolated tree plants nor the changes that take place in their physiognomy during the course of their life span can fully be understood if their components are studied separately.

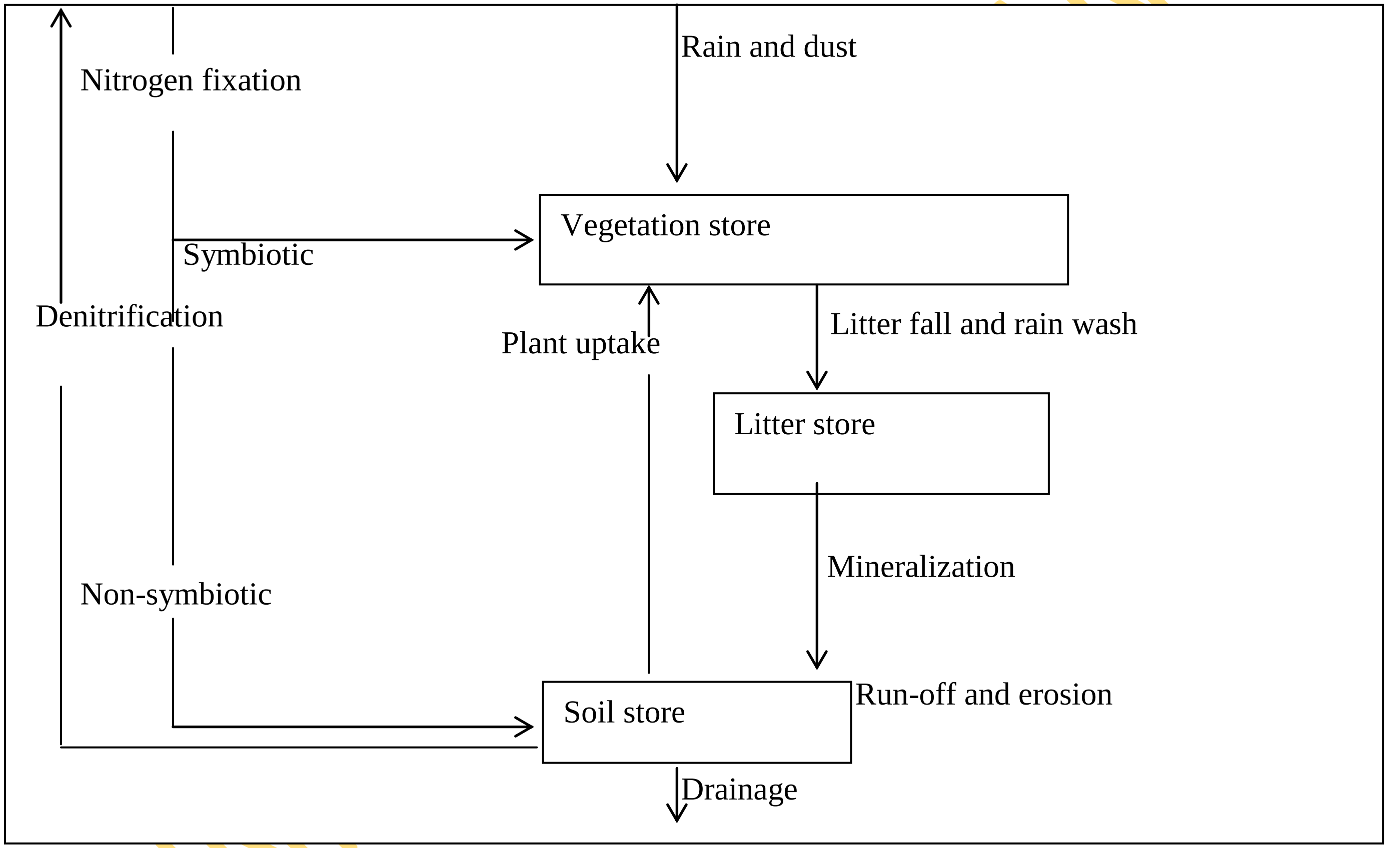


Fig 2.2: Nutrient Cycle between Soil and Forest Fallow (after Nye and Greenland, 1960)

Hence, in this study, a plant-soil system model was adopted to analyze the interrelationships between the soil characteristics and vegetation parameters in the isolated tree plants.

Several studies have assessed the return of nutrient to the soil through litterfall in West Africa. The studies revealed how the return of nutrients to the soil varies in different ecosystem in West Africa. Litterfall and the amount of nutrient returned to the soil were higher in the natural forests than in the monocultural plantations. There was also observed variation in litterfall and nutrient returned to the soil by the same plant species (*Tectona grandis*) studied in the moist rainforest ecosystem of Senegal and drier rainforest ecosystem of Nigeria.

In other studies, it was observed that lowland rainforest ecosystems generally have more nitrogen and lower dry mass/nitrogen ratios in litterfall than nitrogen return in montane rainforest ecosystems (Vitousek, 1984; Jordan, 1985; Sanford and Cuevas, 1996). Many rainforest ecosystems in West Africa have little phosphorus return and very high dry matter/phosphorus ratios in litterfall (Nye, 1960; John, 1973). In a study by Sanford and Cuevas (1996), fine litterfall was predicted from climate, and the residuals of this regression were positively correlated with phosphorus but not nitrogen concentration in litterfall. Fine litterfall (uncorrelated for climate) was also significantly correlated with phosphorus concentration in moist and wet lowland rainforest ecosystems. This suggests that phosphorus but not nitrogen availability limits litterfall in a substantial subset of intact rainforest ecosystems.

The amount and composition of rainwash is collected with gauges, and assessed for nutrient composition. The amount of rain and litter falling beneath a moist rainforest ecosystem in Ghana were measured continuously throughout one year by (Nye, 1960). From this study, litter was considerably rich in nitrogen. On the forest floor it decomposed very rapidly at an average rate of 1.3% per day. 16% of annual rainfall was intercepted by the canopy and evaporated before it reached the ground. Compared with the amount falling as litter, very large amounts of potassium and significant amounts of phosphorus and magnesium, but only a little nitrogen and calcium were washed out of the canopy by rain, with HCO_3 – as the anion. This low amount of nitrogen and calcium washed from canopy was also reported by Hansen (1994), Soulsby and Reynolds (1994).

Amounts of nutrient in litterfall, rainwash and estimated amounts in timber fall were added together to give the rate of nutrient cycling (Nye, 1960). The rate of nutrient storage varies amongst the different ecosystems. In Cote d'Ivoire, studies by Bernhard-Reversat (1977) show that aboveground biomass and storage is higher in the natural rainforest than in the monocultural plantation of 38-year old plantation of *Terminalia ivorensis*. Higher nutrient content were also observed with the natural forest than the monocultural plantations.

2.3.3 The Effect of Trees on Soil Properties

Different tree species selectively immobilize nutrients; hence their effects on soil nutrients vary (Ekanade, 2007). The capacity of trees to maintain soils is shown by the high fertility status and closed nutrient cycling under natural rainforest ecosystems. However, soil nutrient decline usually sets in once there is loss of biodiversity following the conversion of natural forests into monocultural plantation of tree species due to destabilization of the nutrient cycle (Prinz, 1986; Russell, 1987; Aweto, 2001; Ekanade, 2007).

The conversion of rainforests into monocultures of indigenous tree species such as oil palm has been reported by Aweto (2001) to have a similar effect of destabilizing the "closed" nutrient cycle of the natural rainforest. The tree, *Albizia adianthifolia*, has been reported by Prinz (1986) to improve soil organic matter, exchangeable calcium, magnesium, cation exchange capacity and available phosphorus of soil under its canopy in Cameroon.

A study by Aweto (1987) on the physical and nutrient status of soils under rubber reveals that, rubber does not adversely affect soil physical status over time. No significant changes were observed in soil bulk density and total porosity between the first and eighteenth year of rubber plantation establishment. The effects of rubber on soil physical status are quite distinct from those of food crops which Nye and Greenland (1960) reported result in rapid deterioration in soil physical status over time. It was also observed that some nutrient elements decline in level under rubber plantation over time (Aweto, 1987). This leads to much faster rate of mobilization in the standing biomass of the plant than the rate of nutrient recycling in the soil. The trend of a steady decline in the soil mineral-nutrient overtime suggests that soil nutrient deficiency may limit rubber yield during the life of a plantation.

A study by Ekanade (1991), on the nature of soil properties under mature forest and plantations of fruiting and exotic trees in the rainforest fringes of South-Western Nigeria, reveals that most soil properties are significantly degraded under the fruit trees, and some under the exotic trees when compared with those under the forest. The observed decrease in silt and clay fractions may be attributed to mechanical eluviations caused by surface runoff since the fruit tree plantations get disturbed during harvesting periods. Organic matter and exchangeable cations were found to be higher under forest than under the tree crops.

Several studies have been conducted on the effects of cocoa on soil. These studies as carried out by Galletti *et al.* (1956), Kay (1961), Are and Gwynne-Jones (1974), Ogutuga (1975), Areola (1984), Ekanade (1985, 1987, 1988, 1989), Adejuwon and Ekanade (1987), Adesina (1989), Ekanade and Adesina (1991), deduced that cocoa exert impact on rainforest soil. Soil structural properties of bulk density and porosity under cocoa are degraded compared with those under forest. However, these differences have grave implications for the structural development of soils under cocoa. Nicou (1972) observed that relatively small changes in bulk density have a marked effect on root development. It was also deduced that total porosity determines the degree of soil aeration and is positively correlated with nutrient absorption by plants. Soil pH, organic matter content, nitrate – nitrogen, available phosphorus, calcium, magnesium, potassium, sodium, cation exchange capacity and base saturation are all significantly lower under cocoa than under forest (Ekanade, 2007).

The impact of cashew (*Anacardium occidentale*) on forest soil was studied by Aweto and Ishola (1994), and they observed that cashew has no adverse effect on soil organic matter and nutrient status. There were no observed differences between the soils under cashew and soils under the adjoining logged rainforest, in levels of organic carbon, pH, nitrogen, available phosphorus, exchangeable calcium and magnesium. The higher levels of exchangeable potassium under cashew were presumed to be due to the occurrence of more clayey soils under the plantation. Decline in organic matter and nutrient levels in soils under plantation crops reported by Bernhard-Reversat (1987) were not observed in the isolated tree stands studied. This according to Aweto and Ishola (1994) could be due to either the method of land preparation for plantation establishment, or because the plantation was not cropped with field crops.

Several studies have been conducted on soils under *Gliricidia sepium* (Kang et al, 1984; Lal, 1989; Schroth *et al.*, 1995; Maclean *et al*. 2003; Akpokodje and Aweto, 2007). Adesina (1990) observed that *Gliricidia sepium* in bush fallows in South-Western Nigeria had the effect of accumulating organic matter and nutrients in the soil. However, in a study of continuously cultivated soil under *Gliricidia sepium* in South-Western Nigeria (Akpokodje and Aweto, 2007), it was observed that the exotic tree stands do not significantly improve soil organic matter, exchangeable cations and CEC under their canopies, compared with soil outside their canopies in the farmer's fields. Similarly, there was no significant build-up of the extractable micronutrients – iron, copper, manganese and zinc under the tree canopy. There was no significant build-up of organic matter and nutrients in soil under the tree canopy, due to frequent cultivation and burning before cultivation. For each of the two soil types studied, the effect of the tree is similar in respect of organic matter level, total nitrogen, particle size, texture exchangeable cations – calcium, magnesium, potassium and sodium, soil exchange capacity, nutrient – extractable iron, zinc, copper and manganese. The effects of tree crowns in accumulating organic matter and nutrients under their canopies have been widely reported for forest and savanna ecosystems. Other studies on *G. sepium* were carried out in alley farming systems, where tree pruning are regularly applied to the soil as organic manure. Kang et al. (1984) reported that *G. sepium* in alley cropping systems can be sustainable substitutes for shifting cultivation (that is, if the trees are pruned regularly and used to mulch and fertilize field crops such as maize and cassava that are planted in between the rows of *G. sepium* tree). Lal (1989);Schroth et al. (1995); Maclean *et al.* (2003) have also reported the beneficial effects of *G. sepium* in improving crop yields and soil fertility in alley cropping system. Therefore, a fundamental difference exists between alley cropping and traditional cultivation practiced by small scale farmer (Aweto and Akpokodje, 2007).

A study on the impact of *Eucalyptus camadulensis* plantation on an alluvial soil in south-eastern Botswana, by Aweto and Moleele (2004) revealed *E. camadulensis* immobilizes soil nutrients faster and that plantation nutrient cycles are less efficient than in the native acacia woodland. The implication of nutrient depletion, especially of exchangeable calcium and magnesium, in the soil under plantation of *E. camadulensis* is that soil nutrient deficiency may limit plantation productivity after the first, second or third rotation. It is therefore important to rehabilitate the soil by applying appropriate fertilizers and possibly lime to increase soil pH and base saturation at the end of each rotation before replanting (Aweto and Moleele, 2004).

Soils under *Newbouldia laevis* have also been studied. A study by Aweto and Iyanda (2002) on the effects of *N. laevis* on soil subjected to shifting cultivation showed that the mean proportion of organic matter in the soil under *N. laevis* canopy was only slightly higher than that of soil outside the canopy. The lack of substantial build-up of organic matter in the soil under the canopies in this study was attributed to the fact that the plots were frequently cultivated and regularly burnt prior to cultivation. Soil bulk density was lower and total porosity higher under the tree canopies. With the exception of available phosphorus, there was no marked improvement in nutrient levels of the soil under *N. laevis* canopies when compared with soils outside the canopies. The levels of total nitrogen, exchangeable calcium, magnesium and potassium, and cation exchange capacity, were similar in the soil under and outside the canopies. In contrast, Young (1997) who reviewed several studies, reported marked and significant accumulation of these nutrients under the canopies of trees such as *Albizia saman*, *Acacia tortilis*, *Adansonia digitata*, *Parkia biglobosa and Faidherbia albidia.* Available phosphorus was significantly higher under the *N. laevis* canopy. There was also no significant build-up of the micronutrients – iron, zinc and manganese under the canopies of *N. laevis* trees in the farms studied (Aweto and Iyanda, 2002).

Different studies on the effects of cocoa on soil show that cocoa exert impact on the soil. These studies as carried out by Kay (1961), Are and Gwynne-Jones (1974), Ogutuga (1975), Areola (1984), Ekanade (1985,1987, 1988, 1989), Adejuwon and Ekanade (1987), Adesina (1989), Ekanade and Adesina (1991) show that soil physical properties such as porosity and bulk density differed significantly from those under forest. Ekanade (1985; 1988) observed that soil structural properties of bulk density and porosity under cocoa are degraded compared with those under forest. These highly significant differences have grave implications for the structural development of soils under cocoa. Nicou (1972) observed that relatively small changes in bulk density have a marked effect on root development. It is also deduced that total porosity determines the degree of soil aeration and is positively correlated with nutrient absorption by plants. Trouse and Humbert (1961) showed that small changes in bulk density cause roots to become flattened while substantial changes in bulk density cause root restriction. So, the situation whereby the soil total porosity under cocoa degenerates compared with that under forest has implications for the nutrient absorption in aging cocoa plantations (Ekanade, 1985).

Soil pH, organic matter content, nitrate-nitrogen, available phosphorus, calcium, magnesium, potassium, sodium, CEC and base saturation were all significantly lower under cocoa than under forest (Ekanade, 2007).

Unlike the decline in organic matter under cocoa observed by several researchers, Areola (1984) in his study on soil under cocoa for upwards of 8 years in Ibadan region, observed that the fertility status of the soils under cocoa was still very high. Organic matter levels were higher under cocoa than under forest. However, Ahn (1976) noted that the factors responsible for the decline are complex due to changes in structure and nutrient status as well as through erosion and the removal of topsoil. Soil changes under pure stands of cocoa are well documented. Ekanade (1987) found that the supply of exchangeable potassium was strongly depleted after 7 years of continuous cropping with Amazon cocoa. The levels of exchangeable calcium, sodium and magnesium, pH, and organic phosphorus have also been observed to decline under cocoa overtime (Omotoso, 1971; Ekanade, 1985).

In considering the variation pattern of soil properties under cocoa and fallow, Ekanade (1989) in his study on the temporal variations of soil properties under cocoa and fallow observed a drastic reduction in the vegetation biomass in cocoa plantation and fallow plots compared with that in the forest. The nutrient cycling processes are significantly reduced in the cocoa and fallow plant communities with consequent effects on soil nutrient status. For example, Brazilevich and Rodin (1967) found that the nutrient per hectare per year in mature tropical forests in respect of nitrogen, calcium, potassium and silicon are 430kg, 200kg, 200kg and 780kg respectively. However, Greenland and Kowal (1960) had calculated lower values of nutrients for secondary forest regrowth to be 79.4kg, 5.5kg, 33.1kg, 105.8kg and 13.2kg per hectare for nitrogen, phosphorus, potassium, calcium and magnesium respectively. The significant deterioration of calcium, magnesium and potassium under cocoa when compared with fallow could have resulted from the assimilation of nutrient ions in the process of flowering and fruit development. These are removed annually in the cocoa crop and not replaced (Ogutuga, 1975).

The effects of two- tree species – *Combretum apiculatum* and *Peltophorum africanum*, on soil properties in a semi- arid savanna rangeland in Botswana was studied by Aweto and Dikinya (2003). Their study indicated that bulk density was lower and total porosity higher under the tree canopies than in the open savanna. Similarly, soil organic carbon, exchangeable potassium, calcium and magnesium, and cation exchange capacity were higher in soils under the tree canopies, mainly due to the effects of litter accumulation under the tree canopies than in the open grassland. However, the two trees were found to exert similar effects on the soil, thus, it is advisable not to completely eliminate trees from rangeland ecosystems as they help to maintain soil fertility (Aweto and Dikinya, 2003). The level of organic mater, exchangeable potassium, calcium and cation exchange capacity accretion, relative to the open grassland in the surface soil under the two trees was greater than that observed by Kho *et al.* (2001), for the topsoil under the canopies of *Faidherbia albida* on a semi-arid savanna near Niamey, Niger republic. The levels of organic matter, exchangeable potassium, calcium and magnesium in the topsoil under the canopies of *Faidherbia albida* were only 5-20% higher than in soil outside the canopy, while that of *Peltophorum* and *Combretum* as presented by Aweto and Dikinya (2003) were 47-106% higher under canopies than in the open grassland.

The similar effects of two-trees on soil fertility was also observed by Dunham (1991), in his study on the effects of *Acacia albida* and *Kigelia Africana* trees on soil characteristics in Zambezi riverine woodlands. Concentrations of nitrogen, carbon, phosphorus and potassium were higher under tree canopies. Soils were slightly more acidic under *Acacia albida* trees relative to open soil, but were less acidic under *Kigelia africana*. Soil phosphorus concentration was higher under *Kigelia africana* than under *Acacia albida*. The ability of *A. albida* trees to increase soil fertility has been noted often (Charreau and Vidal, 1965; Dancette and Poulain, 1969), but soil enrichment by *A. albida* and those by other tree species has only once been compared. Radwanski and Wickens (1967) compared soils under trees of *A. albida* and *Balanites aegyptiaca* and concluded that soils under *A. albida* were more fertile because carbon, nitrogen and phosphorus concentrations were higher. That study did not compare soils under *A. albida* and *B. aegyptiaca* because the two species did not grow in the same habitat. The differences in the nutrient concentrations of *A. albida* and *K. africana* leaves mirrored the variation in the effects that two tree species had on soil fertility; although, the concentration was only significant for phosphorus. Belsky (1994) observed higher levels of organic matter and nutrients in the soil under the canopies of *Acacia tortilis*, while Pandy *et al.* (2000) also reported higher levels of organic matter and nutrients underneath the crowns of the trees, *Acacia nolitica* in India.

Ekanade (1989) observed a variation in the effect of productive and non-productive kola and soil properties. This study reported that although productive kola trees do degrade soil properties more than the non-productive kola trees, most of the differences are not significant, due possibly to the fact that kola does not continue to bear fruits throughout the year, and that the replenishment of the nutrients withdrawn during harvesting period is effected during off-season through a rapid litter decomposition process (Ekanade, 1987); and by the heavy shade provided to the soil in a humid tropical environment (Charreau, 1972). However, the soil structural properties are significantly degraded under the productive kola trees. Also, soil pH, nitrate- nitrogen and the exchangeable cations (Ca, Mg and K) differ significantly between the productive and the non-productive kola. These exchangeable cations accumulate in the subsoil under the non-productive kola but not under the productive kola. Based on these observations, it has therefore been concluded that productive kola trees absorb more nutrients from the soil than the non-productive kola trees (Ekanade, 1989).

Soil properties under cocoa interplanted with kola was studied by Ekanade (1989, 1990), and findings from the study indicated that soil pH, organic matter, available phosphorus, calcium, potassium and magnesium have their greatest mean values at the topsoil. This implies that a lower mean value of the soil chemical properties is found directly under either cocoa or kola. When cocoa and kola are interplanted in particular way, they have varying impacts on the soil fertility. Ekanade (1990) observed that soil productivity is enhanced by a specific planting arrangement in which litter components of cocoa and kola intermix for a synergistic relationship; this leads to a higher level of organic matter content. Under a monocropping of cocoa, the rate of nutrient return to the soil through litter may be slower than under that of kola. This is because organic materials, especially leaves emanating from kola, do decompose faster than those emanating from cocoa because cocoa leaves are lignified, thus making cocoa leaves decompose very slowly (Ekanade, 1990). It was also observed that correlations exist between organic matter content and other soil chemical properties under cocoa. Therefore, the role of organic matter content in the build-up of soil nutrients appears crucial in all vegetation ecosystems (Ekanade, 1987).

The effect of tree canopy cover on soil fertility in a Nigerian savanna was studied by Isichei *et al.* (1992). The findings from the study indicated that soils under savanna tree canopies have higher levels of organic matter, calcium, magnesium, total exchangeable bases, cation exchange capacity and pH. This can partly be as a result of organic matter accumulation and reduced leaching (Belsky *et al.*, 1989). The organic matter accumulation may be mainly as a result of higher organic matter production by trees and its lower rate of mineralization under three canopies due to reduction in temperature (Bernhard-Reversat, 1982).

With respect to plantation, a study by Ekanade (1991) on the nature of soil properties under mature forest and plantations of fruiting and exotic trees in the rainforest fringes of South-Western Nigeria reveals that, most soil properties are significantly degraded under the fruit trees, and some under the exotic trees when compared with those under the forest. The observed decrease in silt and clay fractions may be attributed to mechanical eluviations caused by surface runoff since the fruit tree plantations get disturbed during harvesting periods. Organic matter and exchangeable cations were found to be higher under forest than under the tree crops.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

The materials and methods of data collection and analyses for this study are as presented in the following subtopics, which comprise selection and design of samples, types of data collected, sources of data collected, procedures for data collection, laboratory analyses of data collected, data presentation and statistical analyses of data.

3.2 SELECTION AND DESIGN OF SAMPLES

A detailed reconnaissance survey revealed that the isolated tree stands contained in the study area have no specific and readily discernible pattern of distribution. Hence, three commonly found cultivated tree species of Indian almond (*Terminalia cattapa*), Avocado pear (*Persea gratissima*), and Mango (*Mangifera indica*), were selected for this study because of their economic importance.

This study was conducted in the existing five quarters of Orogun clan (Umusu, Unukpo, Imodje, Emonu and Ogwa), which in subsequent reference will be called the study area. These quarters were so used in this study to ensure that every part of the study area was evenly covered. In each quarter, 3 stands of each of the isolated tree species were selected, making a total of 45 isolated tree stands sampled (that is, 15 tree stands for each species). The selection of the isolated tree stands was based on the condition that they are not subjected to daily sweeping and burning which expectedly could have impact on the soil properties underneath the trees in the process of nutrient cycling. Also, each tree was so selected such that their canopies are separated from other tree canopies, thereby eliminating relationships with it.

In quantitative analysis of vegetation characteristics, sample areas known as quadrats are delimited for investigation (Chapman, 1976). Thus, in each of the quarters, a sample plot of 30m × 30m divided into 3 quadrats of 10m × 30m was chosen from the adjoining rainforest to serve as control for this study (that is, 15 sample sites were established in the adjoining rainforest). The adjoining rainforest used as control is matured native forest confined to sacred places, and has been referred to as sacred groves or island habitat (Ndakara, 2006; 2009). However, soil samples and plant biomass parameters were collected from these sample points. Soil samples were collected from the 0-15cm and 15cm-30cm depths of the soil profile respectively from each sample point, and will be referred to respectively as “topsoil” and “subsoil” in subsequent sections. Although the choice of 30cm was somewhat arbitrary, the major factor taken into consideration in selecting the limit of depth of soil sampling was that the most significant changes in soil characteristics that take place during the course of nutrient cycling are confined to the topsoil (Nye and Greenland, 1960; Vitousek and Sanford, 1986), particularly the top 15cm. of the soil profile (Sanford and Cuevas, 1996).

For the collection of stemflow, throughfall and litterfall samples, 3 stands of each of the isolated tree species were randomly selected, while 6 rainforest tree species (*Ceiba pentandra*, *Albizia adianthifolia*, *Nauclea diderrichii*, *Alstonia boonei*, *Piptadeniastrum africanum* and *Terminalia superba*) that featured commonly in the adjoining rainforest were chosen as a representative of the rainforest tree species in the study area for stemflow and throughfall sample collection. The 6 sample sites in the adjoining rainforest were not restricted to any species of trees, especially because the tree canopies were not isolated from one another. Also, for the collection of rain water from open space which in subsequent sections will be referred to as incident rainfall, 3 centrally located sample points were established outside the influence of buildings and trees (Ward and Robinson, 2000), and water samples collected served as a control for the rainwash to ascertain the true compositions and returns of nutrient elements in the stemflow and throughfall from the isolated tree stands. Generally, rainwash samples were collected twice in a month, except in the month of December and January where rainfall was observed once respectively. With respect to litterfall, 4 litter bags were set under each of the isolated tree stands and the adjoining rainforest sample sites. In each month, 60 litter samples were collected from February 2010 to January 2011 respectively. This makes a total of 720 litter samples collected.

Therefore, generally put together, a total of 1,566 samples were collected for laboratory analysis (soil samples =120, stemflow = 330, throughfall = 330, incident rainfall = 66, and litterfall = 720). However, data collected for stemflow, throughfall, litterfall and incident rainfall were reported as mean monthly data for each sample site so as to give the monthly data set for the period of 12 months data collection exercise from February 2010 to January 2011.

3.3 TYPES AND SOURCES OF DATA COLLECTED

Data collected for this research comprises the samples collected through field work on litterfall, throughfall, stemflow, incident rainfall, soil, tree heights, tree crown areas, basal areas and tree diameters at breast height.

The data were collected through direct field investigation and measurement. Data on the vegetation characteristics as well as those from stemflow and throughfall were collected from the isolated tree stands and trees in the adjoining rainforests, while the soil data were collected from soils underneath the different isolated tree stands and the adjoining rainforests. Incident rainfall samples were collected from the open space outside the influence of any tree and buildings (Muoghalu and Oakhumen, 2000).

3.4 PROCEDURES FOR DATA COLLECTION

This study involved several technical approaches in the data collection exercise. Since one of the primary objectives of this study is to examine the characteristics of the isolated tree stands and determine their relationships with soil properties underneath, most of the characteristics of the tree stands measured are those that can be readily correlated and regressed on those of the soil parameters. The soil and tree characteristics, together with stemflow and throughfall were also examined with a view to analyzing the nutrients returned to the soil in the process of nutrient cycling.

3.4.1 Tree Heights, Diameters, Crown Areas, Basal Areas and Litter

As earlier stated, tree heights, diameters, crown area, basal area and litter are the vegetation characteristics of the isolated tree stands. Tree height is an important physiognomic property of vegetation, and was determined by the application of the principle of Trigonometry which involved the use of measuring tape, peg and Abney level. The height of tree was measured by standing some distance away from the tree stands to determine the angle of elevation of the top of the trees using Abney level. The distances from the tree stands, the angle of elevation and the height of the observer were recorded and used to calculate for the individual tree heights. The heights of trees were determined for both the isolated tree stands and the adjoining rainforests.

The diameters of the trees were ascertained by first measuring their girths at breast height using a girthing tape, and then converted into diameter values by considering the girths as circumference using C = 2πr, and D = 2r; Where: C = girth measurements; D = diameter; r = radius and Π = 3.142. Tree diameters were also determined for both the isolated tree stands and the adjoining rainforests.

Crown area was determined by measuring the area covered by the canopy of each isolated tree stand using pegs and measuring tape. Results of the crown cover were presented in meter square (m^2). Tree crown area was collected only from the isolated tree stands due to the difficulties associated with the determination of tree crown areas in the adjoining rainforests. The difficulties were those of the crown morphology which made it difficult to ascertain the exact areas covered by individual tree stands in the adjoining rainforest ecosystem. The crowns of trees in the adjoining rainforest are not isolated.

The determination of basal areas of the tree stands involved the measurement of the area covered by tree trunks at ground level. Basal areas were determined by the use of pegs and measuring tapes, and the results were presented in meter square (m^2). The basal areas of tree stands were determined for the isolated tree stands and the adjoining rainforest.

Litter samples were collected from the isolated tree stands and the adjoining rainforest, using litter bags with collection areas measuring $0.5m^2$. Four (4) litter bags were set under each of the isolated tree stands, and each established sample points in the adjoining rainforest to intercept litter before they get to the ground. Therefore, 4 litter bags represented $1m^2$ of the area on the ground from which each sample was collected. The bags were made from sack materials and perforated at the bottom to allow rain water to drip out easily. 60 litter samples were collected in each a month (from February 2010 to January 2011). This makes a total of 720 litter samples collected. The litter samples were put into labeled sacks and taken to the laboratory for analysis on the weight of litter as well as the concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sodium (Na), magnesium (Mg) and pH respectively.

3.4.2 Stemflow, Throughfall and Incident Rainfall

Stemflow was collected by intercepting the water running down the tree stems near the ground, with a rubber channel (¾ mm hose) wound round the tree stands, sealed with bitumastic paste and channeled into 5 litter clean gallons; while throughfall and incident rainfall were collected with improvised funnel-type collector with (10 litre content) buckets placed on stools 3 feet above the ground. The buckets were sealed with polythene sheets, and funnels fixed at the top to intercept the water before it gets to the ground. Four rain gauges (three placed under the isolated tree stands and one placed in open space) were used to confirm the effectiveness of the funnel-type collector, to ensure integrity of sample collections. The water from stemflow, throughfall and incident rainfall were collected into labeled sampling bottles and taken to the laboratory for analysis on the concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sodium (Na), magnesium (Mg) and pH respectively.

3.4.3 Soil Samples

A total of 120 soil samples were collected from the 0-15cm and 15-30cm depth of the soil profiles underneath the different isolated tree stands and the adjoining rainforests respectively. The soil samples were collected by the use of core sampler measuring 3" (7.3cm) in diameter and 4" (10cm) long. The samples were put into labeled polythene bags and taken to the laboratory for analysis on the soil particle size distribution, bulk density, total porosity, water holding capacity, exchangeable cations (exchangeable calcium, magnesium, sodium and potassium), pH, total nitrogen, available phosphorus, organic matter, and cation exchange capacity (C.E.C.) respectively.

3.5 LABORATORY ANALYSES OF SOIL PARAMETERS

The soil properties analysed are those that directly affect the fertility status of the soil. They affect soil productivity and plants growth. The soil characteristics are both physical and nutrient properties of the soil which are (1) particle size distribution; (2) bulk density; (3) total porosity; (4) water holding capacity; (5) exchangeable cations (exchangeable calcium, magnesium, sodium and potassium); (6) pH; (7) total nitrogen; (8) available phosphorus; (9) soil organic matter; and (10) cation exchange capacity.

These soil properties were analysed for both topsoils and subsoils underneath the tree stands and adjoining rainforest respectively.

3.5.1 Particle Size distribution

Particle size distribution influences the growth rate of trees (Medin, 1960; Chapman, 1976) and consequently the rate of vegetation development. Two methods are used to analyze soil particle size distribution. They are the pipette method and hydrometer method (Chapman, 1976). However, this study adopted the hydrometer method because it is much quicker than the pipette method (Aweto, 1978). In this study, it was necessary to adopt the quicker method because of the large number of samples to be analyzed within a relatively short space of time.

3.5.2 Bulk Density and Total Porosity

Bulk density is defined as the mass of soil per unit volume (Birkeland, 1984). It is the ratio of the dry weight of a soil sample to the total volume it occupies in field condition. Bulk density can be used indirectly to assess differences in soil structure and porosity caused by natural process or by management (Marx *et al.*, 1999). Bulk density and porosity determinations can often be related to penetrability by roots (Mirreh and Ketcheson, 1972) or to the suitability for seed germination of a surface soil crust. It is also a measure of the degree of soil compaction (Aweto, 1978). If soil bulk density is high, plant growth is retarded since root development is inhibited. Soil bulk density was determined using the core method (Blake, 1965).

Total porosity is the percentage of the bulk volume of the soil that is not occupied by soil particles (Vomocil, 1965; Chapman, 1978). Total porosity determines the degree of soil aeration and is positively correlated with nutrient absorption by plants (Grabble, 1966). Pore size distribution is vital in consideration of water relationships in soils. Total porosity gives a very different pattern of water retention and release depending on whether it arises from few large pores or many small pores. Total porosity was determined by the core method using the assumed value of 2.65/cubic cm for the soil particle density (Birkeland, 1984).

$$\text{Porosity (\%)} = \left(1 - (\text{Bulk density} / \text{Particle density})\right) \times 100$$

3.5.3 Water Holding Capacity

The ability of the soil to absorb and retain water for plant growth during the periods between rainfalls largely depends on its water holding capacity. Water holding capacity of the soil is the amount of water per unit weight of dry soil when immersed in water under standardized conditions. Water holding capacity of the soil provides a simple means for determining moisture levels required to maintain good plant growth (Birkeland, 1984). The water holding capacity of the soil can be defined as the amount of water retained by the soil at field capacity. Chapman (1976), Tel (1984), and Hossner (1996) defined field capacity as the amount of water held in the soil after the excess gravitational water has been drained away and after the rate of downward movement of water has materially decreased. The soil water holding capacity was determined by saturating the soils samples and later subjected to gravitational draining for 24 hours whilst they were covered with polythene bags to prevent moisture loss through evaporation. Thereafter, the samples were weighed and oven-dried for 24 hours at the temperature of 105ºC. The loss in weight was expressed as a percentage of the oven-dry soil.

3.5.4 Exchangeable cations (Calcium, Sodium, Magnesium and Potassium)

The exchangeable cations are among the most important plant nutrients present in the soil. Decline in soil fertility when the soil is cropped for a long period of time had been attributed to nutrient exhaustion (Agboola, 1970; Tel, 1984). However, their replenishment in the soil is one of the most important processes of nutrient return to the soil in nutrient cycling. In this analysis, the concentrations of the nutrient cations in the soil were obtained by leaching the soil with 1N neutral ammonium acetate. The concentrations of calcium, sodium and potassium were determined with a flame photometer while magnesium was determined with an atomic absorption spectrophotometer.

3.5.5 Soil pH

Soil pH is a measure of the acidity or alkalinity of a soil. It affects the solubility of nutrients in the soil solution and the absorption of nutrient elements by the roots of plants.

The term pH technically only applies to solutions so that analysis must be conducted on a solution (Marx *et al.*, 1999). This study adopted the electrometric method where soil pH was determined potentiometrically in 0.01M calcium chloride using a soil to calcium chloride solution ratio of 1:2. The purpose is to provide a constant soluble salt concentration and thus reduce differences in pH values due to variations in soluble salt in soil water mixtures of various ratios. The major advantage of determining soil pH in 0.01M Calcium chloride rather than in water is that the readings obtained truly reflect the degree of soil base saturation (Peech, 1965; Marx *et al.*, 1999).

3.5.6 Total nitrogen

Nitrogen element in the soil support the production of plants, thus Chapman (1976) and Aweto (1978) opined that poor crop yield in the forest zone is frequently due to shortage of nitrogen in the soil. Soil nitrogen was determined by first digesting the soil with concentrated sulphuric acid (H_2SO_4) and then the nitrogen content of the digest was determined with an auto-analyzer.

3.5.7 Available phosphorus

Shortage of phosphorus is often responsible for the exhaustion of fertility in forest soils (Nye and Greenland, 1960). The term "available phosphorus" refers to those forms of phosphorus that are of immediate significance to plant growth (Nye, 1961; Hart, 1995). Available phosphorus extracts were obtained by leaching the soil with Bray P – 1 extracting solution of Hydrochloric acid and Ammonium floride (0.025N HCl + 0.03N NH_4F). The concentration of available phosphorus was determined colorimetrically with a "spectronic 20" spectrophotometer after the colour had been developed with Murphey and Riley reagent.

3.5.8 Soil Organic Carbon and Organic Matter

Soil organic matter consists of roots, plant residues and soil organisms whether dead or living. It is the major source of plant nutrients such as phosphorus and nitrogen. Organic matter affects the major physical and chemical properties of the soil (Ojeniyi and Agbede, 1980; Marx et al, 1999) which influence soil fertility. Therefore, the soil organic matter can be termed the “Life blood” of soils. Colloidal organic matter possesses cation exchange properties similar to those of clay particles and absorbs calcium, magnesium and potassium on its surfaces. Organic matter decay produces carbon (IV) oxide which forms carbonic acid in the soil. This acid increases the solubility of many soil compounds, thus raising nutrient availability. Organic matter enhances air and moisture relationship for many soil organisms through the effect on soil structure.

In this study, soil organic carbon was determined by the Walkley-Black wet oxidation method. The figures obtained for organic carbon content were converted into organic matter values by multiplying by a factor of 1.724. The Walkley-Black wet oxidation method is more accurate than other methods of determining soil organic matter such as the ignition method.

3.5.9 Cation Exchange Capacity (C.E.C.) and Base Saturation

The cation exchange capacity is a measure of the capacity of the soil to retain and release elements such as K, Ca, Mg, and Na (Marx *et al*., 1999). Soil C.E.C. affects its capacity to supply nutrient cations for plant growth. Soils with high clay or organic matter content tend to have a high C.E.C, while sandy soils have a low C.E.C. In this study, soil C.E.C. was determined by the summation method. In acid soils, such as occur in the study area, the summation method provides the most accurate measure of soil C.E.C. (Chapman, 1976; Marx *et al*., 1999). C.E.C. determination was calculated based on the extracted soil test values converted to milliequivalents.

Base saturation refers to the fraction of the C.E.C. that is occupied by the basic cations, K, Ca, Mg and Na. Base saturation is used to manage soil Na and can be utilized to determine soil Mg availability. When Na exceeds 15% of the C.E.C, water and air infiltration into the soil may be reduced and poor growing conditions may result (Chapman, 1976; Marx et al, 1999). In this study, saturation was calculated as the percentage of the ratio of the individual milliequivalents to the total base milliequivalents.

3.6 LABORATORY ANALYSES OF LITTERFALL PARAMETERS

Litter samples collected were sorted into leaf, fruits and flowers, and small wood litter. Apart from leaf and flower litter, only litter of ≤ 2.5 cm in diameters were included in this study. This is in line with the approaches in studies by Muoghalu *et al* (1993), Hermansah et al (2002), and Wood *et al* (2006). The litter samples were dried to constant mass in an electric oven at temperature of 105ºC for 24 hours. Analyses were based on litter production and nutrient concentrations. The laboratory analyses were carried out in the Chemistry Department of the Delta State University Abraka, under the strict instructions and supervision of Mr E. Aghogho.

3.6.1 Litter Production:

The oven-dried litter samples were weighed by the use of "Top Loading Electronic Balance". The weights represented the litter production for the isolated tree stands and the adjoining rainforest, and reported in g/m^2.

3.6.2 Nutrient Concentrations in Litterfall

The oven-dried litter samples were ground into powdery form and analyzed for pH and for the concentrations of elements such as nitrogen, phosphorus, potassium, calcium, sodium and magnesium. To determine the concentrations of nitrogen and phosphorus, this study adopted the approach of a modified Kjeldahl digestion on a Tecator 2000 Digestion System. This method uses 30% hydrogen peroxide and concentrated sulphuric acid (H_2SO_4) at 360ºC to hydrolyze organic P and N to inorganic forms. Digested samples were kept in the refrigerator until analyzing the matrix colorimetrically on an Lapse Flow Solution IV Auto-analyzer in accordance with the U.S. Environmental Protection Agency (EPA) method for the determination of total P and N. The nutrient cations (K, Ca, Na and Mg) were analyzed by digesting the ground litter samples in HNO_3 / H_2O_2 on a block at 105ºC, as adopted by (Adedeji, 2008). The samples were then re-dissolved in 50ml of 10% nitric acid for analysis using Spectro CIROS CCDE Inductively Coupled Argon Emission Plasma Spectrometry (ICP). The pH values were determined by the use of pH meter.

3.7 LABORATORY ANALYSES OF RAINWASH PARAMETERS

The samples from rainwash (stemflow and throughfall) and incident rainfall were analysed for the concentrations of nutrient elements which are nitrogen, phosphorus, potassium, calcium, sodium, magnesium and pH. Prior to analysis, water samples were filtered through ash-free filter papers with a pore size < 2 µm (Schleicher and Schuell, blue band 589^3), except for the measurement of pH which unfiltered samples were used. Thus measured concentrations of N and P could not be referred to as dissolved; instead the term "total organic" (TO) was used.

3.7.1 Nutrient Concentrations and Returns in Rainwash

The filtered water samples were analysed for the concentrations of elements such as nitrogen, phosphorus, potassium, calcium, sodium and magnesium. In the determination of total N, a segmented Flow Analyser (SANplus, SA 2000/4000, Skalar Analytical BV, The Netherlands) was used. Total N was digested using alkaline persulfate and ultraviolet (UV) to convert $NH_4 – N$ and organic N to $NO_3 – N$. The same equipment was used for analysis of total P ($P_{tot,,}$ persulfate-UV digestion) and PO_4-P. Detection limits were (0.04 mg / l for total P and 0.05 mg / l for PO_4-P) in rainfall, stemflow and throughfall. Total organic nitrogen (TON) and Total organic phosphorus (TOP) were calculated as difference between total amounts and inorganic forms (TON = N_{tot} - $NH_4 – N$ - ($NO_3 – N$ + $NO_2 – N$), TOP = $P_{tot,}$ - PO_4-P). Cation concentrations (Na, Ca, Mg and K) were determined by atomic absorption spectrometry (AAS Atomic Absorption Spectrum – 932, GBC Scientific Equipment pty Ltd. Australia). However, the pH of water was measured electrochemically. The calculation of throughfall water and nutrient returns was based on the projected crown area; while stemflow was based on the chemical enrichment as adopted in a study by Levia (2003). Calculation of stemflow returns was based on the chemical enrichment because stemflow inputs seep into the soil only around a tree bole. The extent of chemical enrichment of stemflow from each test tree during a precipitation event was computed using an enrichment ratio. Enrichment ratios were quantified by considering the total quantity of each nutrient draining from the tree in stemflow in relation to the amount of each nutrient that would be expected in an open rain gauge occupying an area equivalent to the tree trunks' basal area (Levia and

Herwitz, 2000). The enrichment ratio is only valid when leaching occurs (i.e. chemical concentration of rainwash is greater than the mean chemical concentration of the incident gross precipitation for a nutrient element).

3.8 DATA PRESENTATION AND METHODS OF DATA ANALYSES

Results of all data are presented in tables, while analyses were based on the application of both descriptive and inferential statistical techniques. The descriptive statistics employed are the mean, standard deviation and the use of graphs; while the inferential statistics employed are the one-way analysis of variance (ANOVA), step-wise multiple regression analysis, multiple correlation analysis, and the Pearson's bivariate correlation analysis. The statistical analyses were carried out using the SPSS 15.0 version, and are all in response to the objectives, research questions and hypotheses of this study as stated in chapter one respectively.

The techniques of mean and standard deviation were used to determine the mean and standard deviation values for the characteristics of the trees, soil properties, concentrations and returns of nutrient elements in stemflow, throughfall and litterfall respectively. Graphs were used to show the seasonal variations in litter production and the returns of nutrient elements through stemflow, throughfall and litterfall. The one-way analysis of variance statistics (ANOVA) was employed to determine the differences in the tree characteristics, soil properties, nutrient concentrations and returns to the soil through rainwash and litterfall amongst the isolated tree stands and the adjoining rainforest. Step-wise multiple regression analysis was employed to evaluate the relationships between measures of plant biomass parameters (tree heights, diameters and crown areas) with soil organic matter. Multiple correlation analysis was employed to determine the interrelationships between plant biomass parameters and soil properties. While Pearson's bivariate correlation analysis was employed to ascertain the relationships between litter production and nutrient returns via litterfall; litter production and soil nutrient status characteristics; as well as soil nutrient properties and nutrients returned to the soil via litterfall, throughfall and stemflow respectively.

Analysis of Variance Statistics (ANOVA):

The analysis of variance statistics, commonly abbreviated as ANOVA, is employed in comparing the difference in the means of three or more variables. One might think that the t-test can be used when comparing the means of three or more samples, by comparing two means at a time. There are several reasons why the t-test should not be used in this case:

i. When one is comparing two means at a time, the rest of the means under study are ignored. With the ANOVA test, all the means are compared simultaneously.

ii. When one is comparing two means at a time and making all pair-wise comparisons, the probability of rejecting the null hypothesis when it is true is increased since the more t-tests that are conducted, the greater the likelihood of getting significant differences by chance alone.

iii. The greater the number of means there are to compare, the greater is the number of t-tests that are needed (Bluman, 1995).

With the ANOVA test, two different estimates of the population variance are made: between - group variance and the within- group variance. The two ways to calculate the ANOVA are the One-way ANOVA and the two-way ANOVA. The one-way ANOVA involves only one independent variable, while the two-way ANOVA involves two independent variables. The two approaches according to Bluman (1995), give the same result. Therefore, this study employed the one-way ANOVA approach. When the differences are significant, post – hoc test were conducted using the Least Square Difference (LSD) approach, to determine where the differences amongst the means are. Both the analysis of variance and post-hoc tests were computed using the SPSS 15.0 version.

Multiple Regression Analysis:

Regression models are used to express the functional relationship between a dependent variable and predictor or independent variables such that the independent variables are used to explain the variations in the dependent variable. It shows how changes in the independent variables affect the dependent variables. Generally, multiple regression analysis is used when there are several independent variables contributing to the variation of the dependent variable and one cannot control all of them. This analysis can be used to make accurate predictions for the dependent variables (Bluman, 1995).

The interest of this exercise is to examine the relationships between the returns of nutrient elements to the soil called the predictor, and the production of litter which is the criterion. Therefore, the application of regression analysis was deemed appropriate through the step-wise method using the SPSS 15.0 version.

The Step-wise Multiple Regression Method:

Step-wise regressions derive the best regression equation from a set of explanatory variables on a step by step basis. Step-wise is the most sophisticated of the multiple regression approaches (Hauser, 1974; Bluman, 1995). Each variable is entered in sequence and its value assessed. If adding the variable contributes to the model then it is retained, but all other variables in the model are then re-tested to see if they are still contributing to the success of the model. If they no longer contribute significantly they are removed. Thus, this method should ensure that you end up with the smallest possible set of independent variables included in your model. There are two main types of step-wise procedures – the forward selection and the backward elimination. This study employed the backward elimination procedure which did not involve knowing the levels of correlation amongst the set variables before they are entered into the SPSS dialogue box for analysis. The advantages of step-wise multiple regressions include:

- It enables one to examine quickly not only the magnitude and significance of the joint contributions made to the variance explained by all independent variables taken together but also that made by each individual variable.
- It helps to eliminate from the regression equation such variables that do not make any meaningful contribution to the explanation of the dependent variable. In a multiple regression analysis involving very many independent variables, say ≥ 10, this can be very useful since we can then pay attention to only those independent variables whose contributions are significant.
- It should always result in the most parsimonious model. This could be important if one is interested in knowing the minimum number of variables needed to predict the dependent variable.

There are different ways that the relative contribution of each predictor variable can be assessed. In the "simultaneous" method (which SPSS calls the 'Enter method'), the researcher specifies the set of predictor variables that make up the model. The success of this model in predicting the criterion variable is then assessed. In statistical methods, the order in which the predictor variable are entered into (or taken out of) the model is determined according to the strength of their correlation with the criterion variables. Indeed, there are several versions of this method, called forward selection and the backward elimination. In forward selection, SPSS enters the variables into the model one at a time in an order determined by the strength of their correlation with the criterion variable. The effect of adding each is assessed as it is entered, and variables that do not significantly add to the success of the model are excluded. In backward elimination, SPSS enters all the predictor variables into the model. The weakest predictor variable is then removed and the regression re-calculated. If this significantly weakens the model then the predictor variable is re-entered otherwise it is deleted. The procedure is then repeated until only useful predictor variables remain in the model.

From the SPSS results obtained, the Adjusted R square value tells us the percentage of variance which our model accounts for. The ANOVA table presents the overall significance of our model. The standardized Beta coefficients give a measure of the contribution of each variance to the model. A large value indicates that a unit change in this predictor variable has a large effect on the criterion variable. The t-values give a rough indication of the impact of each predictor variable which is a big absolute t-value, and small p-value suggests that a predictor variable in having a large impact on the criterion variable.

Simple and Multiple Correlation Analyses

The simple correlation analysis approach measures the nature and strength of association between the dependent variable and an independent variable. It therefore involves the assessment of the level of relationship between two sets of observations, if the two variables of interest satisfy the assumptions of parametric statistics which include assumptions that the data are drawn from normally distributed populations, that they are measured on the interval or ratio scales, that the populations from where the data were drawn have the same variance or a known ratio of variances that the observations are independent. This study employed the Pearson's bivariate technique using the SPSS 15.0 version in the analysis of the relationships between litter production and the returns of nutrient elements to the soil through litterfall.

Multiple correlation analysis is a direct extension of the simple correlation analysis. The multiple correlation coefficient measures the strength of the association between the dependent variable and the linear combination of all the independent variables. In other words, multiple correlations enable us to know the extent to which all the independent variables taken together will help to explain the dependent variable. In the same way, the partial correlation helps to determine the additional contribution to the explanation of dependent variable made by any particular independent variable. These contributions are usually obtained by squaring the correlated r.

In this study, the multiple correlation analyses were computed using the SPSS 15.0 version. However, for both the simple linear and multiple correlation analyses, r-value indicates strength and direction of the correlation; the p-value indicates the probability of obtaining an r-value by chance. If p-value is ≤ the probability level, the null hypothesis is rejected.

CHAPTER FOUR

CHARACTERISTICS OF THE TREE STANDS AND THE SOIL UNDER THEM

4.1 INTRODUCTION

The characteristics of tree stands vary significantly amongst the isolated tree stands and the adjoining rainforest. The observed variations as evidenced in this study have varying effects on the soil properties underneath the tree stands in the process of nutrient cycling. Data on the characteristics of tree stands (tree height, tree diameter at breast height, tree crown area and tree basal areas) and the results of laboratory analyses of soil parameters (soil physical and nutrient properties), under the isolated tree stands and the adjoining rainforest areas are presented and discussed in this chapter. This chapter also presents findings on the variations in tree characteristics and soil properties underneath the isolated tree stands and the adjoining rainforest.

4.2 CHARACTERISTICS OF THE TREE STANDS

The characteristics of the tree stands vary significantly amongst the isolated trees and the adjoining rainforest. The extent and level of variations obtained using the One-Way analysis of variance statistics are as presented in appendix 4.1. However, multiple comparisons of the means using the LSD test show the pairs within which the mean differences are significant (appendixes 4.2- 4.5 respectively).

4.2.1 Tree Heights

Tree height accounts for the vegetation physiognomy which represents the functional characteristics of vegetation that explains plants adaptive role for survival in existing environment. With respect to nutrient cycling, tree height plays a functional role in the spread of tree litter. Shorter tree stands tend to concentrate their litter directly underneath the tree stands, while taller trees spread their litter due to the influence of wind before they get to the ground. Table 4.1 shows the mean and standard deviation values of the tree heights for the different isolated tree stands and the adjoining rainforest areas.

Table 4.1: Tree heights in meters per sample site

Sample sites	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
1	12.72	15.76	12.08	35.00
2	17.16	15.99	11.05	34.77
3	15.04	13.22	11.75	36.02
4	12.91	16.01	12.02	35.00
5	14.00	14.12	10.98	35.20
6	13.01	14.03	11.77	35.38
7	15.42	13.82	11.65	33.81
8	17.01	15.81	12.02	34.59
9	16.81	15.86	12.00	35.04
10	14.24	16.00	10.94	36.00
11	13.32	17.02	11.86	35.50
12	15.31	15.50	11.76	35.20
13	17.00	14.58	12.01	36.11
14	15.01	15.41	11.32	34.92
15	12.89	16.24	11.45	33.78
Mean	**14.79**	**15.29**	**11.64**	**35.09**
S.D	**1.65**	**1.08**	**0.40**	**0.70**
C.V (%)	**11.16**	**7.06**	**3.44**	**2.00**

The mean height of trees for Indian almond (*Terminalia cattapa*), Mango (*Mangifera indica*), Avocado pear (*Persea gratissima*) and Adjoining Rainforest are 14.79, 15.29, 11.64 and 35.09 meters respectively. The results show that the isolated tree stands are shorter in height compared with trees in the adjoining rainforest. This is evidenced from the results of the analysis of variance as presented in appendix 4.1, which shows that there is a significant difference in the height of the isolated tree stands and the adjoining rainforest at the 0.05 confidence level. However, the result of multiple comparisons using the LSD test shows the pair of means where significant differences are observed (appendix 4.2).

4.2.2 Tree Diameters at Breast Height

The mean tree diameters at breast height vary among the isolated tree stands and the adjoining rainforest. The highest mean value was recorded in the *Mangifera indica* stands while the lowest value was recorded in the *Persea gratissima* stands.

Table 4.2 shows the mean and standard deviation values for the tree diameters. The mean values for Indian almond (*Terminalia cattapa*), Mango (*Mangifera indica*), Avocado pear (*Persea gratissima*) and Adjoining rainforest are 0.41, 0.72, 0.29 and 0.33 meters respectively. Mango tree stands have the largest diameter while the smallest diameter is recorded with the Avocado pear stands. Results of the one-way analysis of variance (appendix 4.1) show that there is a significant difference in the observed tree diameters amongst the isolated tree stands and the adjoining rainforest areas at the 0.05 confidence levels. However, the result of multiple comparisons using the LSD test shows the pair of means where significant differences are observed (appendix 4.3).

Table 4.2 Tree diameters at breast height per sample site in meters

Sample sites	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
1	0.38	0.69	0.37	0.29
2	0.48	0.64	0.22	0.42
3	0.41	0.73	0.30	0.36
4	0.37	0.78	0.21	0.28
5	0.39	0.75	0.16	0.43
6	0.37	0.72	0.31	0.34
7	0.40	0.62	0.28	0.27
8	0.42	0.78	0.36	0.31
9	0.41	0.61	0.41	0.24
10	0.36	0.54	0.31	0.19
11	0.49	0.88	0.29	0.25
12	0.34	0.76	0.26	0.32
13	0.38	0.72	0.34	0.41
14	0.38	0.74	0.28	0.37
15	0.52	0.77	0.24	0.43
Mean	**0.41**	**0.72**	**0.29**	**0.33**
S.D	**0.05**	**0.08**	**0.07**	**0.08**
C.V (%)	**12.20**	**11.11**	**24.14**	**24.24**

4.2.3 Tree Crown Areas

The crown areas of the isolated tree stands vary significantly amongst the tree species. This shows the extent of the areas covered by each of the tree stands, and has been observed to have impact on the soil under them in the process of nutrient cycling.

Table 4.3 shows the mean and standard deviation values of the tree crown areas. The means for Indian almond (*Terminalia cattapa*), Mango (*Mangifera indica*) and Avocado pear (*Persea gratissima*) are 143.55, 158.98 and 83.19 square meters (m^2) respectively. There is a significant difference in the tree crown areas among the isolated tree stands at the 0.05 confidence levels (appendix 4.1).

Table 4.3 Crown areas of isolated tree stands in m^2

Sample sites	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)
1	134	176.0	90.0
2	160	159.0	63.0
3	143	150.0	73.0
4	134.4	159.8	70.0
5	137.8	150.1	83.0
6	136.2	150.0	97.0
7	144.0	151.2	85.0
8	158.6	160.2	90.2
9	150.8	159.8	90.6
10	140.2	158.7	88.5
11	137.0	178.6	84.5
12	143.1	153.6	78.9
13	160.0	149.1	89.4
14	140.1	158.2	86.2
15	134.1	170.4	78.6
Mean	**143.55**	**158.98**	**83.19**
S.D	**9.41**	**9.40**	**9.05**
C.V (%)	**6.56**	**5.91**	**10.88**

4.2.4 Tree Basal Areas

The basal areas of the tree stands vary amongst the isolated tree stands and the adjoining rainforest. Just like the observed values for the tree diameters at breast height, the highest mean value for the tree basal areas was got from the stands of *Mangifera indica*, while the lowest value was observed in the *stan*ds of *Persea gratissima*.

Table 4.4 presents the mean and standard deviation values for the tree basal areas. The mean values for Indian almond (*Terminalia cattapa*), Mango (*Mangifera indica*), Avocado pear (*Persea gratissima*) and adjoining rainforest are 0.21, 0.60, 0.12 and 0.15 square meters (m^2) respectively. Results of the one-way analysis of variance (appendix 4.1) revealed that there is a significant difference in the basal areas of the tree stands amongst the isolated trees and the adjoining rainforest areas at the 0.05 confidence level. However, the result of multiple comparisons using the LSD test shows the pair of means where significant differences are observed (appendix 4.5).

Table 4.4: Basal areas of tree stands in m²

Sample sites	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
1	0.18	0.55	0.17	0.12
2	0.28	0.47	0.07	0.22
3	0.21	0.61	0.12	0.14
4	0.17	0.67	0.07	0.11
5	0.19	0.64	0.04	0.22
6	0.19	0.59	0.13	0.15
7	0.22	0.45	0.11	0.10
8	0.21	0.69	0.17	0.13
9	0.18	0.43	0.21	0.08
10	0.16	0.42	0.13	0.08
11	0.28	0.86	0.12	0.09
12	0.15	0.65	0.10	0.14
13	0.18	0.60	0.15	0.21
14	0.20	0.63	0.11	0.18
15	0.30	0.68	0.09	0.24
Mean	**0.21**	**0.60**	**0.12**	**0.15**
S.D	**0.05**	**0.12**	**0.04**	**0.05**
C.V (%)	**23.81**	**20.00**	**33.33**	**33.33**

4.3 SOIL PROPERTIES UNDER TREE STANDS

The soil properties under the isolated tree stands are discussed under the soil physical and nutrient status properties respectively.

4.3.1 Soil Physical Properties

The physical properties of soils under the isolated tree stands and adjoining rainforest areas investigated are the total porosity, bulk density, water holding capacity and the soil particle size distribution (sand, silt and clay).

Total Porosity: Total porosity increases with increase in the biomass parameters of the isolated tree stands. This is because as the biomass of isolated tree stands increases, the density of roots in the soil also increases and consequently, the soil is loosened and opened up. Also, the addition of organic matter to the soil enhances the aggregation of soil particles thus improving the soil porosity. As can be observed from tables 4.5 and 4.6, the mean values of total porosity under adjoining rainforest for both the topsoil and subsoil are higher than those of the isolated tree stands.

Table 4.5 shows the mean and standard deviation of the total porosity values of the topsoil layer for the different sample sites. The mean total porosity values for the avocado pear, mango, Indian almond and adjoining rainforest are 55.15%, 59.44%, 57.79% and 63.81%. Although the mean values are close, the highest mean value was observed in the adjoining rainforest. Therefore, the lowest value observed with Avocado pear indicates a lower biomass parameter than with the Mango and Indian almond trees which are also isolated tree stands.

Table 4.6 shows the mean and standard deviation of the total porosity values for the subsoil layer of the different sample sites. The mean total porosity values for the avocado pear, mango, Indian almond and adjoining rainforest are 65.52%, 65.42%, 63.44% and 68.49%; while their standard deviation values are 3.66%, 4.14%, 2.56% and 5.24% respectively.

The differences in both the topsoil and subsoil total porosity amongst the isolated tree stands and the adjoining rainforest are significant at the 5% confidence levels, when tested with the analysis of variance statistics (Tables 4.37 and 4.38). Results of the one-way analysis of variance tests as presented in tables 4.37 and 4.38 are all significant at the 5% confidence levels for all soil parameters tested.

Table 4.5: Total porosity values (%) for the topsoil

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian almond (*Terminalia cattapa*)	Adjoining Rainforest
1	58.9	56.2	58.1	59.6
2	51.7	61.1	56.6	62.3
3	54.7	58.1	63.0	64.5
4	53.2	68.3	54.7	69.8
5	60.0	57.4	55.5	58.9
6	55.5	57.7	56.6	66.8
7	54.0	59.6	55.9	67.6
8	54.0	57.0	56.2	60.8
9	59.6	66.4	56.6	60.0
10	54.3	56.2	57.0	65.3
11	52.8	57.4	59.3	64.2
12	54.7	58.5	65.3	60.4
13	54.7	57.7	58.9	63.4
14	55.1	65.3	57.0	64.5
15	54.0	54.7	56.2	69.1
Mean	**55.15**	**59.44**	**57.79**	**63.81**
S.D	**2.45**	**4.06**	**2.88**	**3.48**
C.V	**4.44**	**6.83**	**4.98**	**5.45**

Table 4.6: Total porosity values (%) for the subsoil

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	63.0	62.3	63.4	62.3
2	69.1	66.4	60.8	65.3
3	65.7	65.5	67.6	69.1
4	61.9	74.3	59.3	71.3
5	66.8	65.7	65.3	61.5
6	67.2	66.4	60.0	74.7
7	61.1	63.0	65.7	77.4
8	63.4	65.5	63.0	63.4
9	68.3	74.0	63.8	63.8
10	67.6	61.1	64.2	74.3
11	60.8	62.3	66.4	68.3
12	66.0	61.9	66.8	62.3
13	72.1	64.2	62.3	69.1
14	69.8	67.9	61.9	69.8
15	60.0	60.8	61.1	74.7
Mean	**65.52**	**65.42**	**63.44**	**68.49**
S.D	**3.66**	**4.14**	**2.56**	**5.24**
C.V (%)	**5.59**	**6.33**	**4.04**	**7.65**

Bulk Density: Bulk density is a physical property of the soil which is markedly modified by the presence of plants (Crocker, 1967; Marx et al, 1999). During cropping, soil bulk density tends to increase due to the impact of rain drops that break down soil aggregates. The finer soil fragments are washed down to seal soil pores therefore making the soil more compact. As the isolated tree stands develop on the other hand, soil bulk density tends to decrease with increasing maturity because plant roots open up the soil thus making it less compact. Although the mean bulk density values of the soil under the isolated exotic tree stands appear higher than that from the adjoining rainforest, the level of variability is higher under the rainforest than under the isolated tree stands.

Table 4.8 shows the group means, standard deviation and coefficient of variation values of the topsoils under the isolated tree stands and the adjoining rainforest. The mean values for the Avocado pear, Mango, Indian almond and adjoining rainforest are 0.91 g/cm^3, 0.92 g/cm^3, 0.96 g/cm^3 and 0.84 g/cm$^{3;}$ while the coefficient of variation values are 10.99%, 11.96%, 7.29% and 16.67% respectively.

Although the lowest group mean values for the soil bulk density for the isolated tree stands and the adjoining rainforest are relatively close as observed in the topsoil, the lowest value was also observed in the adjoining rainforest. The adjoining rainforest has lower mean value of soil bulk density than the isolated exotic tree stands.

However, results of the Analysis of Variance (Table 4.37) shows that the calculated F-value of 18.457 is greater than the critical table F-value of 2.84. There is therefore a significant difference in the bulk density values of the topsoil layer amongst the isolated tree stands and the adjoining rainforest.

Table 4.8: Bulk density values in g/cm^3 for the topsoil

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	0.98	1.00	0.97	1.00
2	0.82	0.89	1.04	0.92
3	0.91	0.94	0.86	0.82
4	1.01	0.68	1.08	0.76
5	0.88	0.91	0.92	1.02
6	0.87	0.89	0.90	0.67
7	1.03	0.98	0.91	0.60
8	0.97	0.94	0.98	0.97
9	0.84	0.69	0.96	0.96
10	0.86	1.03	0.95	0.68
11	1.04	1.00	0.89	0.84
12	0.90	1.01	0.88	1.00
13	0.74	0.95	1.00	0.82
14	0.80	0.85	1.01	0.80
15	1.06	1.04	1.03	0.67
Mean	**0.91**	**0.92**	**0.96**	**0.84**
S.D	**0.10**	**0.11**	**0.07**	**0.14**
C.V (%)	**10.99**	**11.96**	**7.29**	**16.67**

Table 4.9: Bulk density values in g/cm^3 for the subsoil

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	1.09	1.16	1.11	1.07
2	1.28	1.03	1.15	1.00
3	1.20	1.11	0.98	0.94
4	1.24	0.84	1.20	0.80
5	1.06	1.13	1.18	1.09
6	1.18	1.12	1.15	0.88
7	1.22	1.07	1.17	0.86
8	1.22	1.14	1.16	1.04
9	1.07	0.89	1.15	1.06
10	1.21	1.16	1.14	0.92
11	1.25	1.13	1.08	0.95
12	1.20	1.10	0.92	1.05
13	1.20	1.12	1.09	0.97
14	1.19	0.92	1.14	0.94
15	1.22	1.20	1.16	0.82
Mean	**1.19**	**1.08**	**1.12**	**0.96**
S.D	**0.07**	**0.11**	**0.08**	**0.09**
C.V (%)	**5.88**	**10.19**	**7.14**	**9.38**

Table 4.9 shows the mean and standard deviation of bulk density values for the subsoils under the isolated tree stands and the adjoining rainforest. The group means of bulk density values for the Avocado pear, Mango, Indian almond and adjoining rainforest are 1.19 g/cm^3, 1.08 g/cm^3, 1.12 g/cm^3 and 0.96 g/cm^3; while their standard deviation values are 0.07 g/cm^3, 0.11 g/cm^3, 0.08 g/cm^3 and 0.09 g/cm^3 respectively. However, result of the Analysis of Variance (table 4.38) shows that the calculated F-value of 3.559 is greater than the critical table F-value of 2.84. There is therefore a significant difference in the bulk density values of the subsoil layer amongst the isolated tree stands and the adjoining rainforest.

Soil Water Holding Capacity: Improvements in the water holding capacity of the soil under isolated tree stands as they attain maturity is an important feature of the soils under the rainforest, at least on predominantly coarse soil texture such as occurs in the study area. From table 4.10, the mean water holding capacity values per sample site for the Avocado pear, Mango, Indian almond and adjoining rainforest are 52.97%, 55.00%, 56.18% and 60.69% respectively.

The adjoining rainforest has a higher capacity to hold water than the isolated tree stands. However, amongst the isolated tree stands, Avocado pear has the lowest capacity to hold water. Therefore, it can possibly be deduced that shade cast on the soil owing to wider crown area which shields the soil, affects the soil capacity to hold water. This inference owes much to the fact that the lowest water holding capacity was observed from the Avocado pear stands where the smallest tree crown area was observed.

However, the result of the Analysis of Variance (Table 4.37) shows that the calculated F-value of 24.933 is greater than the critical table F-value of 2.84. There is therefore a significant difference in the water holding capacity values of the topsoil layer amongst the isolated tree stands and the adjoining rainforest.

Although water holding capacity in the topsoil is relatively high under the isolated tree stands and the adjoining rainforest, the group mean values appeared a little higher in the subsoil under the isolated tree stands and the adjoining rainforest. This obviously shows that the capacity of the subsoil to hold water is a little higher than that with the topsoil.

Table 4.10: Water holding capacity values of the topsoil (%)

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	53.6	60.2	53.4	62.4
2	56.4	56.7	51.1	58.3
3	50.3	52.3	56.3	60.7
4	52.9	54.7	58.5	62.5
5	52.3	53.7	52.7	63.6
6	54.6	52.1	58.2	59.4
7	54.3	57.8	57.9	56.8
8	52.4	54.6	54.8	64.5
9	54.9	54.7	56.8	60.3
10	51.7	55.4	57.3	66.2
11	54.3	54.2	53.2	56.9
12	52.2	50.1	58.9	59.5
13	52.8	53.2	59.6	62.2
14	51.5	58.5	57.4	61.5
15	50.4	56.8	56.6	55.5
Mean	**52.97**	**55.00**	**56.18**	**60.69**
S.D	**1.71**	**2.66**	**2.55**	**3.02**
C.V (%)	**3.23**	**4.84**	**4.54**	**4.98**

Table 4.11: Water holding capacity values of the subsoil (%)

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	54.1	62.1	55.4	66.1
2	56.7	59.1	52.9	64.2
3	52.5	54.5	58.7	66.0
4	61.5	58.5	60.3	66.7
5	58.8	54.2	57.2	67.1
6	59.3	56.3	59.8	63.4
7	59.4	59.7	60.5	61.2
8	57.4	57.4	55.4	68.6
9	60.4	56.3	57.1	63.7
10	53.2	60.2	58.1	68.2
11	60.9	56.0	54.5	62.1
12	55.4	53.4	59.5	64.3
13	56.2	54.2	60.2	66.7
14	53.5	60.5	58.3	65.6
15	55.7	58.5	58.7	60.2
Mean	**57.00**	**57.39**	**57.77**	**64.94**
S.D	**2.95**	**2.67**	**2.32**	**2.50**
C.V (%)	**5.18**	**4.65**	**4.02**	**3.85**

As shown in table 4.11, the group means values for the water holding capacity of the subsoils under the Avocado pear, Mango, Indian almond and adjoining rainforest are 57.00%, 57.39%, 57.77% and 64.94% respectively.

Increase in the organic matter content of the topsoil in a large measure, accounts for the improvement in the soil water holding capacity with an increase in the age of fallow (Nye and Greenland, 1960). There is a built-up of soil organic matter through time. The amount of clay present in the soil, in contrast, was lowest in almost all the tree species and the adjoining rainforest than sand and silt compositions. This explains why soil organic matter more strongly affects the extent of improvement of soil water holding capacity than soil clay content.

However, result of the Analysis of Variance (Table 4.38) shows that the calculated F-value of 31.417 is greater than the critical table F-value of 2.84. There is therefore a significant difference in the water holding capacity values of the subsoil layer amongst the isolated tree stands and the adjoining rainforest.

Soil Particle Size Distribution: Particle size distribution is one of the most fundamental soil attributes. Since plants are not capable of modifying the proportions of the inorganic components of the soil, the textural composition of the soil does not change as cultivated tree crops (such as the isolated tree stands) develop with time. Sand is the predominant soil fraction in the two layers of the soil, accounting for about 70% by weight of the mineral fragments in the soil. However, the soils are texturally similar under the tree stands, except in a few cases where differences occurred.

Table 4.12 shows the mean proportions and standard deviation values of sand per sample site for the topsoil of the Avocado pear, mango, Indian almond and adjoining rainforest are 72.36%, 69.48%, 72.60% and 74.04%; while their standard deviation values are 2.43%, 1.62%, 1.77% and 2.19% respectively.

Sand sized fractions in the topsoil vary. This is as observed in the result of the Analysis of Variance (Table 4.37) which shows that the calculated F-value of 13.271 is greater than the critical table F-value of 2.84. There is therefore a significant difference in the percentage values of sand in the topsoil layer amongst the isolated tree stands and the adjoining rainforest at the 5% confidence level.

Table 4.12: Percentage of sand content in the topsoils

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	72.08	68.31	70.31	69.81
2	73.10	70.63	73.76	76.36
3	68.12	72.41	74.32	76.21
4	73.50	71.02	73.89	76.02
5	70.04	70.58	71.02	73.84
6	75.86	70.52	74.72	69.98
7	74.11	68.36	74.36	75.43
8	72.10	67.82	70.38	76.12
9	74.20	69.12	71.20	74.84
10	69.07	69.52	73.98	75.50
11	75.13	67.68	70.28	74.48
12	73.04	70.42	71.52	74.38
13	74.38	67.08	74.30	72.47
14	72.18	71.22	73.96	73.76
15	68.42	67.57	71.02	71.40
Mean	**72.36**	**69.48**	**72.60**	**74.04**
S.D	**2.43**	**1.62**	**1.77**	**2.19**
C.V (%)	**3.36**	**2.33**	**2.44**	**2.96**

Table 4.13: Percentage of sand content in the subsoils

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	70.10	69.63	71.56	72.73
2	73.63	67.46	71.08	67.78
3	71.20	66.14	71.30	68.42
4	72.02	67.82	71.81	68.36
5	68.36	68.21	71.02	69.44
6	72.44	70.32	70.92	70.37
7	71.76	75.46	71.22	70.51
8	70.48	71.16	71.37	71.13
9	72.89	71.18	70.98	72.18
10	71.18	67.01	71.06	72.67
11	69.00	69.08	71.65	70.12
12	71.92	68.34	71.98	67.87
13	71.98	67.36	72.00	69.17
14	68.24	70.86	71.79	68.82
15	72.18	71.20	71.77	70.81
Mean	**71.16**	**69.42**	**71.43**	**70.03**
S.D	**1.62**	**2.37**	**0.38**	**1.66**
C.V (%)	**2.28**	**3.41**	**0.53**	**2.37**

The mean proportion of sand in the subsoil varies amongst the isolated tree stands and the adjoining rainforest. The mean values for the Avocado pear, mango, Indian almond and adjoining rainforest are 71.16%, 69.42%, 71.43% and 70.03% respectively (Table 4.13). However, result of the Analysis of Variance (Table 4.38) shows that the calculated F-value of 4.855 is greater than the critical table F-value of 2.84. There is therefore a significant difference in the percentage values of the subsoil layer amongst the isolated tree stands and the adjoining rainforest.

The amount of silt and clay in the soils is small, being less than 30% of the inorganic fractions of the two soil layers. From table 4.14, the mean proportions of silt per sample site for the topsoil of the Avocado pear, mango, Indian almond and adjoining rainforest are 16.67%, 19.70%, 14.54% and 13.47%; while the standard deviation values are 2.43%, 1.57%, 1.17% and 0.98% respectively.

This shows that there is variation in the compositions of silt in the topsoil. However, result of the Analysis of Variance (Table 4.37) shows that the calculated F-value of 42.295 is greater than the critical table F-value of 2.84. Therefore, the observed variation in the mean proportions of silt in the topsoil layer amongst the isolated tree stands and the adjoining rainforest is significant at the 5% confidence level.

The proportion of silt is lowest with the soils under the adjoining rainforest and highest under the avocado pear. In contrast with the percentage composition in the subsoil, silt proportion reduces with increase in the depth of the soil profile. However, the lowest proportion was observed under the adjoining rainforest and the highest value from soils under Mango tree stands.

Table 4.14: Percentage of silt content in the topsoils

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	17.92	20.46	13.80	15.41
2	14.89	19.23	14.50	12.56
3	21.52	16.57	15.76	12.59
4	16.42	18.16	15.70	12.70
5	17.94	18.86	14.62	13.70
6	13.02	18.80	14.04	15.16
7	15.33	20.66	14.78	13.21
8	16.01	20.88	13.08	12.70
9	14.93	19.80	12.12	12.78
10	18.93	19.58	15.04	12.38
11	14.37	21.23	14.75	12.96
12	16.54	19.16	15.52	13.44
13	14.56	22.80	15.68	14.05
14	16.54	18.01	15.92	13.70
15	21.06	21.27	12.82	14.74
Mean	**16.67**	**19.70**	**14.54**	**13.47**
S.D	**2.43**	**1.57**	**1.17**	**0.98**
C.V (%)	**14.58**	**7.97**	**8.05**	**7.28**

Table 4.15: Percentage of silt content in the subsoils

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	11.06	11.04	12.47	12.67
2	12.94	15.31	14.54	9.89
3	11.02	13.46	10.16	10.46
4	11.10	13.16	14.77	10.38
5	12.36	11.81	12.06	10.84
6	11.89	14.68	15.06	10.98
7	11.59	13.56	16.10	11.00
8	12.85	11.02	9.87	11.02
9	11.98	15.01	11.23	12.16
10	12.77	12.89	15.46	12.56
11	11.68	14.00	16.35	10.92
12	11.56	13.44	12.04	10.22
13	11.69	14.82	10.32	10.88
14	11.94	14.94	16.09	10.56
15	11.90	11.30	13.51	10.87
Mean	**11.89**	**13.36**	**13.34**	**11.03**
S.D	**0.62**	**1.49**	**2.32**	**0.82**
C.V (%)	**5.22**	**11.15**	**17.39**	**7.43**

Table 4.15 shows the mean and standard deviation values for the proportions of silt in the subsoils under the isolated tree stands and the adjoining rainforest. The mean proportions of silt for the Avocado pear, mango, Indian almond and adjoining rainforest are 11.89%, 13.36%, 13.34% and 11.03%; while the standard deviation values are 0.62%, 1.49%, 2.32% and 0.82% respectively. The observed variations in the composition of silt amongst the sample sites were tested with the Analysis of variance statistics. However, result of the Analysis of Variance (Table 4.38) shows that the calculated F-value of 9.154 is greater than the critical table F-value of 2.84. There is therefore a significant difference in the composition of silt in the subsoils amongst the isolated tree stands and the adjoining rainforest.

The clay fraction of the soil increases down the profile. The highest mean value in the topsoil was observed under Indian almond while the lowest was from mango stands. In contrast with the subsoil, the highest mean value was observed under the adjoining rainforest while the lowest value was from under Mango tree stands.

Table 4.16 shows the mean and standard deviation values for the proportions of clay fractions in the topsoils under the isolated tree stands and the adjoining rainforest. The mean proportions of clay for the Avocado pear, mango, Indian almond and adjoining rainforest are 10.98%, 10.82%, 12.86% and 12.49%; while their standard deviation values are 0.72%, 0.37%, 2.63% and 1.26% respectively. These values show that there are differences in the clay compositions of the topsoils. However, result of the Analysis of Variance (Table 4.37) shows that the calculated F-value of 7.071 is greater than the critical table F-value of 2.84. There is therefore a significant difference in the mean clay values of the topsoil layer amongst the isolated tree stands and the adjoining rainforest.

Table 4.16: Percentage of clay content in the topsoils

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	10.00	11.23	15.89	14.78
2	12.01	10.14	11.74	11.08
3	10.36	11.02	9.92	11.20
4	10.08	10.82	10.41	11.28
5	12.02	10.56	14.36	12.46
6	11.12	10.68	11.24	14.86
7	10.56	10.98	10.86	11.36
8	11.89	11.30	16.54	11.18
9	10.87	11.08	16.68	12.38
10	12.00	10.90	10.98	12.12
11	10.50	11.09	14.97	12.56
12	10.42	10.42	12.96	12.18
13	11.06	10.12	10.02	13.48
14	11.28	10.77	10.12	12.54
15	10.52	11.16	16.16	13.86
Mean	**10.98**	**10.82**	**12.86**	**12.49**
S.D	**0.72**	**0.37**	**2.63**	**1.26**
C.V (%)	**6.56**	**3.42**	**20.45**	**10.09**

With respect to the subsoils, the mean proportion of clay for the Avocado pear, mango, Indian almond and adjoining rainforest are 16.49%, 17.56%, 15.23% and 18.95%; while the standard deviation values are 2.13%, 2.09%, 2.32% and 2.45% respectively (Table 4.17). However, result of the Analysis of Variance (Table 4.38) shows that the calculated F-value of 7.380 is greater than the critical table F-value of 2.84. There is therefore a significant difference in the mean clay compositions of the topsoil layer amongst the isolated tree stands and the adjoining rainforest.

The discussion above has revealed that the soils in the different sites selected for this study are very similar in terms of textural composition, except in a few cases as earlier indicated. In all the sample sites, both the topsoils and subsoils contain the highest percentage of sand particles; while the proportion of silt is higher than that of the clay. Generally, the compositions of clay particles are more in the subsoils than in the topsoils. However, in spite of the textural homogeneity, some variations exist between the sites belonging to the different tree species. Indian almond trees for instance, tend to have more clay in the topsoil underneath their canopies than the other isolated tree stands, but has the lowest clay than the other isolated tree stands in the subsoils. As will be expected, some of the observed variations in the level of nutrients and water holding capacity of the soils may be attributed partly to the variations in the clay content of the soil.

Table 4.17: Percentage of clay content in the subsoils

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	18.84	19.33	15.97	14.60
2	13.43	17.23	14.38	22.33
3	17.78	20.40	18.54	21.12
4	16.88	19.02	13.42	21.26
5	19.28	19.98	16.92	19.72
6	15.67	15.00	14.02	18.65
7	16.65	15.98	12.68	18.49
8	16.67	17.82	18.76	17.85
9	16.13	13.81	17.79	15.66
10	16.05	20.10	13.48	14.77
11	11.32	16.92	12.00	18.96
12	16.52	18.22	15.98	21.91
13	16.33	17.82	17.68	19.95
14	19.82	14.20	12.12	20.62
15	15.92	17.50	14.72	18.32
Mean	**16.49**	**17.56**	**15.23**	**18.95**
S.D	**2.13**	**2.09**	**2.32**	**2.45**
C.V (%)	**12.92**	**11.90**	**15.23**	**12.93**

4.3.2 Soil Chemical Properties

Soil Organic Matter: Soil organic matter is an important source of plant nutrients. As pointed out earlier, the build-up of organic matter is one of the most important changes that take place in soils under the rainforest ecosystem. Indeed, this is applicable in the soils under the isolated tree stands. This is because, soil organic matter not only influences the amount of nutrients that accumulate under tree stands but also soil physical attributes such as porosity, water holding capacity and soil crumb structure which have a direct bearing on the level of soil fertility (Aweto, 1978).

There is variation in the soil organic matter content of the soils under the isolated tree stands. Table 4.18 and 4.19 show the mean and standard deviation values of the organic matter compositions of the topsoils and subsoils respectively under the isolated tree stands and the adjoining rainforest areas.

The mean values for the topsoils under Avocado pear, mango, Indian almond and adjoining rainforest areas are 4.06%, 5.20%, 5.0%, and 6.33%; while the standard deviation values are 0.76%, 0.49%, 0.31% and 0.59% respectively. Organic matter content is higher under the adjoining native rainforest than under the isolated tree stands, which has their highest value under mango tree stands and the lowest value under Avocado pear stands. However, result of the Analysis of Variance (Table 4.37) shows that the calculated F-value of 41.718 is greater than the critical table F-value of 2.84. There is therefore a significant difference in the organic matter compositions of the topsoil layer amongst the isolated tree stands and the adjoining rainforest.

Table 4.18: Organic matter content (%) of the topsoil

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	4.35	5.48	5.03	5.41
2	3.31	5.26	5.20	6.33
3	4.41	4.93	5.28	7.03
4	4.90	5.07	5.15	5.41
5	3.20	5.24	4.67	6.40
6	3.10	4.62	5.12	5.66
7	4.80	4.24	4.79	7.07
8	4.52	5.28	4.12	6.50
9	4.50	4.76	5.41	6.91
10	3.34	6.07	4.93	7.29
11	3.12	5.10	5.10	6.26
12	3.10	5.24	5.20	5.76
13	4.80	6.14	5.03	6.31
14	4.91	5.31	5.00	6.28
15	4.60	5.26	4.97	6.29
Mean	**4.06**	**5.20**	**5.00**	**6.33**
S.D	**0.76**	**0.49**	**0.31**	**0.59**
C.V (%)	**18.72**	**9.42**	**6.20**	**9.32**

Table 4.19: Organic matter content (%) of the subsoil

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	0.93	2.19	1.93	1.95
2	1.40	2.05	1.72	2.60
3	1.30	1.97	1.90	3.74
4	0.97	2.14	2.28	1.95
5	1.10	1.94	1.91	2.96
6	1.14	1.31	2.05	2.10
7	0.79	1.84	2.10	3.83
8	0.67	1.86	1.66	2.94
9	0.69	1.90	2.17	3.47
10	0.74	2.78	1.59	3.92
11	1.50	1.98	2.31	2.91
12	1.60	1.93	2.09	2.45
13	0.71	2.93	2.03	2.54
14	0.90	2.07	1.45	2.96
15	0.86	1.86	1.79	2.97
Mean	**1.02**	**2.05**	**1.93**	**2.89**
S.D	**0.31**	**0.38**	**0.25**	**0.64**
C.V (%)	**30.39**	**18.54**	**12.95**	**22.15**

In contrast to the organic matter content of the subsoil layer, the mean values for Avocado pear, mango, Indian almond and adjoining rainforest areas are 1.02%, 2.05%, 1.93% and 2.89%; while the standard deviation values are 0.31%, 0.38%, 0.25% and 0.64% respectively (Table 4.19). The differences in the soil organic matter content of the subsoils amongst the isolated tree stands are significant at the 5% confidence level when tested with the analysis of variance statistics (Table 4.38). However, results of multiple comparisons using the LSD test shows the pairs of means where the differences are significant (appendix 4.19).

Total Nitrogen:

Tables 4.20 and 4.21 show the mean and standard deviation values of the total nitrogen content of the topsoil and subsoil respectively. Soil total nitrogen is higher under the adjoining rainforest than under the isolated tree stands. This is similar to the observed pattern of soil organic matter content. This is as it should be since soil organic matter is the chief 'store' of soil nitrogen (Aweto, 1978; Vitousek and Sanford, 1986).

The group means of nitrogen in the topsoils under Avocado pear, mango, Indian almond and adjoining rainforest areas are 0.45%, 0.48%, 0.53% and 0.59%; while the standard deviation values are 0.07%, 0.05%, 0.05% and 0.12% respectively (Table 4.20).

From table 4.21, the mean values of nitrogen in the subsoils under Avocado pear, Mango, Indian almond and adjoining rainforest areas are 0.19%, 0.20%, 0.23% and 0.27%; while the standard deviation values are 0.05%, 0.03%, 0.03% and 0.04% respectively. This shows that total nitrogen content is higher under the native adjoining rainforest than the isolated tree stands. Amongst the isolated tree stands for both soil layers of the oil profile, Indian almond (*Terminalia cattapa*) recorded the highest group mean values while Avocado pear (*Persea gratissima*) recorded the lowest group mean values.

Table 4.20: Total nitrogen content (%) of the topsoil

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	0.38	0.46	0.48	0.52
2	0.46	0.52	0.53	0.51
3	0.36	0.50	0.46	0.76
4	0.52	0.43	0.54	0.61
5	0.32	0.38	0.58	0.74
6	0.47	0.42	0.61	0.56
7	0.50	0.51	0.49	0.82
8	0.39	0.53	0.57	0.67
9	0.49	0.48	0.53	0.54
10	0.48	0.47	0.60	0.63
11	0.37	0.45	0.45	0.47
12	0.51	0.54	0.54	0.38
13	0.45	0.52	0.52	0.46
14	0.48	0.48	0.51	0.70
15	0.52	0.53	0.55	0.48
Mean	**0.45**	**0.48**	**0.53**	**0.59**
S.D	**0.07**	**0.05**	**0.05**	**0.12**
C.V (%)	**15.56**	**10.42**	**9.43**	**20.34**

Table 4.21: Total nitrogen content (%) of the subsoil

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	0.23	0.21	0.22	0.24
2	0.21	0.22	0.23	0.30
3	0.20	0.24	0.20	0.31
4	0.25	0.20	0.23	0.22
5	0.14	0.14	0.24	0.30
6	0.21	0.16	0.30	0.28
7	0.22	0.21	0.19	0.32
8	0.13	0.23	0.25	0.31
9	0.20	0.17	0.22	0.27
10	0.10	0.20	0.28	0.35
11	0.12	0.18	0.18	0.21
12	0.26	0.22	0.21	0.21
13	0.14	0.22	0.20	0.23
14	0.19	0.16	0.23	0.29
15	0.28	0.20	0.20	0.26
Mean	**0.19**	**0.20**	**0.23**	**0.27**
S.D	**0.05**	**0.03**	**0.03**	**0.04**
C.V (%)	**26.32**	**15.00**	**13.04**	**14.82**

Total nitrogen content is higher in the topsoils than in the subsoils under the isolated tree stands and the adjoining rainforest. This is as to be expected since the organic matter content of the soils is also generally higher in the topsoils than in the subsoils. There is no appreciable build-up of total nitrogen in the subsoils of the isolated tree stands and those of the adjoining rainforests in the sample sites. Therefore it emphasizes that total nitrogen accumulation under tree stands is confined to the topsoils as in the case of organic matter. However, the observed variation in the nitrogen content of the subsoils are significant at the 5% confidence levels when tested with the Analysis of variance statistics (Table 4.38).

Available Phosphorus: The build-up of available phosphorus in the soils under tree stands is of considerable importance because; its deficiency in the soil for tree plant utilization is a factor that frequently limits their growth and production.

Table 4.22 shows that the mean and standard deviation values of the available phosphorus contents of the topsoils. The mean values for Avocado pear, mango, Indian almond and adjoining rainforest areas are 11.76 mg/kg, 12.09 mg/kg, 13.87 mg/kg and 14.86 mg/kg; while the standard deviation values are 4.26 mg/kg, 2.62 mg/kg, 1.93 mg/kg and 1.82 mg/kg respectively. The mean and standard deviation values for the phosphorus content of the topsoil revealed that there are differences in phosphorus content of the topsoils among the sample sites, which was confirmed to be significant at the 5% two-tailed levels when tested with the Analysis of variance statistics (Table 4.38).

Also, table 4.23 shows the mean and standard deviation values of the subsoils under the isolated tree stands and the adjoining rainforests. The group mean values for Avocado pear, mango, Indian almond and adjoining rainforest areas are 6.22 mg/kg, 6.79 mg/kg, 7.61mg/kg and 7.58mg/kg respectively; while the standard deviation values are 1.16mg/kg, 1.15 mg/kg, 0.71 mg/kg and 2.07 mg/kg respectively. The highest value of available phosphorus in the topsoils is recorded in the adjoining rainforest while the lowest value is recorded under Avocado pear. In the subsoil, the highest value of available phosphorus is recorded under Indian almond while the lowest value is recorded under Avocado pear. In contrast, available phosphorus content is higher in the topsoils than in the subsoils in all the sample sites.

Table 4.22: Available phosphorus content of the topsoil in mg/kg

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	26.18	13.14	17.01	14.10
2	11.04	12.74	16.21	13.24
3	13.26	10.78	10.38	15.27
4	9.74	10.26	14.41	14.21
5	8.62	11.94	12.32	18.31
6	11.16	13.68	10.16	16.07
7	10.22	16.82	14.50	12.52
8	14.03	18.12	15.11	13.36
9	10.18	10.19	13.22	16.41
10	11.32	12.22	12.39	17.16
11	9.61	12.76	13.86	14.00
12	8.45	10.32	15.32	12.13
13	11.29	9.14	14.98	16.24
14	10.32	10.02	14.14	16.25
15	11.04	9.28	13.97	13.61
Mean	**11.76**	**12.09**	**13.87**	**14.86**
S.D	**4.26**	**2.62**	**1.93**	**1.82**
C.V (%)	**36.25**	**21.67**	**13.92**	**12.25**

Table 4.23: Available phosphorus content of the subsoil in mg/kg

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	5.28	7.28	8.30	7.21
2	6.26	7.08	8.24	6.11
3	8.80	6.92	6.24	8.13
4	5.16	6.47	7.92	7.08
5	5.02	6.21	6.87	10.02
6	6.24	6.38	6.56	9.61
7	6.12	8.24	7.96	5.38
8	8.83	10.16	8.23	6.01
9	6.47	6.12	7.50	10.00
10	6.21	6.84	7.56	12.26
11	5.38	6.75	8.29	7.14
12	5.14	6.00	8.18	5.16
13	6.21	5.62	7.90	7.18
14	6.04	6.01	7.87	7.15
15	6.18	5.78	6.54	5.28
Mean	**6.22**	**6.79**	**7.61**	**7.58**
S.D	**1.16**	**1.15**	**0.71**	**2.07**
C.V (%)	**18.65**	**16.94**	**9.33**	**27.31**

Exchangeable Cations:

Changes in the levels of exchangeable calcium, magnesium, potassium and sodium will be examined in this section. Tables 4.24, 4.25, 4.26 and 4.27 respectively show the mean and standard deviation values for the concentrations of exchangeable calcium, magnesium, potassium and sodium in the topsoils of the sample sites. The pattern of variation shown by each of the four cations is the same for magnesium, potassium and sodium (adjoining rainforest > Indian almond > mango > Avocado pear); but different from that of calcium which is Indian almond > mango > Avocado pear > adjoining rainforest respectively. Tables 4.28, 4.29, 4.30 and 4.31 respectively show the mean and standard deviation values for the concentrations of exchangeable calcium, magnesium, potassium and sodium in the subsoils of the isolated tree stands and rainforest. Potassium and sodium show the same pattern (adjoining rainforest > Indian almond > Avocado pear > mango), while calcium and magnesium patterns varied in the subsoils. Generally, the concentrations of exchangeable cations are higher in the topsoils than in the subsoils.

Table 4.24 shows the mean and standard deviation values of the exchangeable calcium in the topsoils under the isolated tree stands and the adjoining rainforest areas. The mean values for the Avocado pear, mango, Indian almond and adjoining rainforest are 712.4 mg/kg, 769.4 mg/kg, 794.5 mg/kg and 709.7 mg/kg respectively, while their standard deviation values are 65.65 mg/kg, 38.06 mg/kg, 10.27 mg/kg and 369.11 mg/kg respectively. However, result of the Analysis of Variance (Table 4.37) shows that the calculated F-value of 95.95 is greater than the critical table F-value of 2.84.

There is therefore a significant difference in the concentration of exchangeable calcium in the topsoil layer amongst the isolated tree stands and the adjoining rainforest.

Table 4.24: Concentrations of exchangeable calcium in the topsoil in mg/kg

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	712	798	781	1461
2	611	763	800	1878
3	815	671	798	1054
4	638	782	792	1887
5	701	776	780	1080
6	710	784	801	1902
7	618	790	804	1934
8	698	808	791	1898
9	770	766	803	1879
10	802	797	779	2023
11	811	778	778	1042
12	684	695	799	1955
13	747	765	808	1808
14	677	767	803	1694
15	692	801	800	2150
Mean	**712.40**	**769.40**	**794.47**	**709.67**
S.D	**65.65**	**38.06**	**10.27**	**369.11**
C.V (%)	**9.22**	**4.95**	**1.29**	**52.01**

Table 4.25: Concentrations of exchangeable magnesium in the topsoil in mg/kg

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	301	280	298	510
2	197	281	287	386
3	199	196	242	489
4	300	248	289	396
5	302	283	195	504
6	204	298	288	497
7	289	212	240	388
8	294	267	253	485
9	301	229	256	512
10	198	261	287	499
11	197	280	199	487
12	201	197	297	496
13	204	209	188	506
14	196	278	300	510
15	299	283	292	489
Mean	**245.47**	**253.47**	**260.73**	**476.93**
S.D	**51.01**	**35.41**	**40.03**	**45.85**
C.V (%)	**20.78**	**13.97**	**15.35**	**9.61**

From table 4.25, the mean values of the exchangeable magnesium concentration in the topsoils under the Avocado pear, mango, Indian almond and adjoining rainforest are 245.47mg/kg, 253.47 mg/kg, 260.73 mg/kg and 476.93 mg/kg, while their standard deviation values are 51.01mg/kg, 35.41mg/kg, 40.03mg/kg and 45.85 mg/kg respectively. From the results of ANOVA test (Table 4.37), the observed variations in the mean concentrations of exchangeable magnesium in the topsoils were significant at the 5% confidence level. Calculated F-value of 99.604 is greater than the critical table F-value of 2.84. There is therefore a significant difference in the concentrations of exchangeable magnesium in the topsoil layer amongst the isolated tree stands and the adjoining rainforest.

Table 4.26 shows the mean and standard deviation values for the concentrations of exchangeable potassium in the topsoils of the sample sites. The group mean value in mg/kg for Avocado pear, mango, Indian almond and adjoining rainforest are 57.80, 60.73, 61.73 and 116.47 respectively; while their standard deviation values are 5.67, 4.43, 5.69 and 26.69 mg/kg respectively. Result of the Analysis of Variance (table 4.37) shows that the calculated F-value of 60.073 is greater than the critical table F-value of 2.84. There is therefore a significant difference in the concentrations of exchangeable potassium in the topsoil layer amongst the isolated tree stands and the adjoining rainforest.

The concentrations of exchangeable sodium in the topsoils vary amongst the isolated tree stands and the adjoining rainforest. The group mean values for the Avocado pear, mango, Indian almond and adjoining rainforest are 47.33, 54.87, 55.67 and 88.47 mg/kg respectively; while their standard deviation values are 6.75, 4.72, 6.25 and 15.99 mg/kg respectively.

Table 4.26: Concentrations of exchangeable potassium in topsoil in mg/kg

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	51	57	54	131
2	57	68	58	107
3	54	64	69	98
4	48	59	62	108
5	62	56	67	104
6	66	57	63	98
7	56	60	54	156
8	49	67	55	86
9	60	56	56	97
10	61	59	68	125
11	58	68	64	94
12	57	65	69	185
13	67	60	57	107
14	63	58	68	139
15	58	57	62	112
Mean	**57.80**	**60.73**	**61.73**	**116.47**
S.D	**5.67**	**4.43**	**5.69**	**26.69**
C.V (%)	**9.81**	**7.30**	**9.22**	**22.92**

Table 4.27: Concentrations of exchangeable sodium in the topsoil in mg/kg

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	59	58	57	106
2	47	55	60	98
3	34	56	68	85
4	52	54	55	77
5	56	49	57	109
6	40	63	49	66
7	44	56	59	100
8	52	45	55	88
9	49	48	42	81
10	48	54	47	76
11	36	57	60	98
12	48	56	61	56
13	47	60	56	105
14	50	53	56	104
15	48	59	53	78
Mean	**47.33**	**54.87**	**55.67**	**88.47**
S.D	**6.75**	**4.72**	**6.25**	**15.99**
C.V (%)	**14.26**	**8.60**	**11.23**	**18.07**

However, result of the Analysis of Variance (Table 4.37) shows that the calculated F-value of 55.464 is greater than the critical table F-value of 2.84. There is therefore a significant difference in the concentrations of exchangeable sodium in the topsoil layer amongst the isolated tree stands and the adjoining rainforest. Variations in the concentration of exchangeable cations in the topsoils under isolated tree stands and the rainforest is due possibly to differences in the build-up of nutrient cations in the topsoil which can be attributed to the observed differences in the biomass parameters of the tree stands, return of nutrients to the soil through the fall and mineralization of litter which presumably exceeded the rate of uptake and loss through leaching.

The group mean values of the exchangeable cations for the subsoils under the isolated tree stands and the adjoining rainforest are all lower than those of the topsoils in the same sample sites. Their differences were all significant at the 5% confidence levels when tested with the independent samples t-statistics. This is because the build-up of nutrient cations is confined to the topsoil layer of the soil profile for reasons explained earlier. Table 4.28 shows the mean and standard deviation values of the exchangeable calcium concentrations in the subsoils under the isolated tree stands and the adjoining rainforest areas. The group mean values for avocado pear, mango, Indian almond and adjoining rainforest are 353.67mg/kg, 359.6mg/kg, 358.47mg/kg and 539.67mg/kg respectively, while the standard deviation values are 30.57mg/kg, 18.6mg/kg, 32.36mg/kg and 150.62mg/kg respectively. The highest concentration was observed under the adjoining rainforest, while the lowest mean concentration was observed under the Avocado pear stands.

Although the patterns of variation in the concentrations of exchangeable cations in the subsoil varied significantly at the 5% confidence levels, the groups mean values are generally higher in the subsoils under the adjoining rainforest areas than in the isolated tree stands.

Table 4.28: Concentrations of exchangeable calcium in the subsoil in mg/kg

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	343	351	331	386
2	321	359	372	788
3	404	340	330	398
4	341	365	349	456
5	362	354	322	587
6	351	368	392	342
7	328	402	390	515
8	380	351	346	477
9	330	352	380	499
10	408	350	321	757
11	401	352	332	343
12	348	337	317	656
13	326	359	408	486
14	341	354	390	668
15	321	400	397	737
Mean	**353.67**	**359.60**	**358.47**	**539.67**
S.D	**30.57**	**18.60**	**32.36**	**150.62**
C.V (%)	**8.64**	**5.17**	**9.03**	**27.91**

Table 4.29 shows the concentrations of exchangeable magnesium in the subsoils under the isolated tree stands and the adjoining rainforest areas. The mean values for the avocado pear, mango, Indian almond and adjoining rainforest are 91.93mg/kg, 100.6mg/kg, 101.20mg/kg and 195.27mg/kg; while the standard deviation values are 16.40mg/kg, 9.21mg/kg, 14.45mg/kg and 69.85mg/kg respectively.

The highest concentration was observed under the adjoining rainforest while the lowest concentration was observed under the avocado pear. The pattern of variations indicates that the concentrations of exchangeable magnesium are lower amongst the isolated tree stands than with the adjoining rainforest areas. However, while the highest standard deviation was observed under the adjoining rainforest, the lowest value was observed under the Mango tree stands.

The pattern of variations of exchangeable magnesium and potassium are similar in terms of the standard deviation values, but strikingly different from that observed under the exchangeable sodium. Indeed, it could be inferred here that the general pattern of nutrient concentrations in the subsoil is due probably to the variations in return of nutrients to the soil underneath the tree stands and the adjoining rainforest areas. The contributions of individual tree stands to soil nutrient concentrations will be addressed in the next chapters.

Table 4.29: Concentrations of exchangeable magnesium in the subsoil in mg/kg

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	110	117	114	299
2	84	116	97	198
3	109	96	100	195
4	119	98	116	107
5	121	99	81	288
6	98	94	108	196
7	88	98	99	102
8	90	94	97	134
9	97	95	98	228
10	78	104	102	101
11	75	113	76	129
12	78	82	112	198
13	85	103	80	263
14	70	98	129	294
15	77	102	109	197
Mean	**91.93**	**100.60**	**101.20**	**195.27**
S.D	**16.40**	**9.21**	**14.45**	**29.85**
C.V (%)	**17.84**	**9.16**	**14.28**	**15.29**

Table 4.30: Concentrations of exchangeable potassium in the subsoil in mg/kg

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	16	14	16	36
2	14	16	18	50
3	19	18	22	23
4	18	16	23	31
5	21	15	22	29
6	23	16	19	18
7	20	19	16	30
8	16	18	17	25
9	20	14	15	19
10	21	15	18	22
11	17	18	21	22
12	15	20	25	56
13	18	19	19	19
14	18	11	20	30
15	17	17	23	31
Mean	**18.20**	**16.40**	**19.60**	**29.40**
S.D	**2.48**	**2.39**	**3.00**	**11.01**
C.V (%)	**13.63**	**14.57**	**15.31**	**37.45**

Table 4.30 shows the concentrations of exchangeable potassium in the subsoils under the isolated tree stands and the adjoining rainforest areas. The mean values for the Avocado pear, Mango, Indian almond and adjoining rainforest are 18.20mg/kg, 16.40mg/kg, 19.60mg/kg and 29.40mg/kg respectively; while their standard deviation values are 2.48mg/kg, 2.39mg/kg, 3.0mg/kg and 11.01mg/kg respectively. As earlier observed with the other exchangeable cations, the highest mean value was observed under the adjoining rainforest while the lowest value was under the Mango tree stands. This pattern is the same with the observed pattern under the subsoils for the concentrations of exchangeable sodium (Table 4.31). The mean concentrations of sodium in the subsoils under avocado pear, mango, Indian almond and the adjoining rainforest are 19.93mg/kg, 1873mg.kg, 20.13mg/kg and 28.13mg/kg respectively; while their group standard deviation values are 3.52mg/kg, 2.22mg/kg, 3.73mg/kg and 3.46mg/kg respectively.

Although the mango tree stands recorded the lowest mean value for the concentrations of sodium in the subsoils, the other two isolated tree stands (avocado pear and Indian almond) have close mean values which are approximately the same. The differences in the concentrations of exchangeable cations amongst the isolated tree stands and the adjoining rainforest were significant at the 5% level of confidence (Table 4.38).

Table 4.31: Concentrations of exchangeable sodium in the subsoil in mg/kg

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	18	21	20	29
2	21	18	26	31
3	20	21	24	29
4	17	19	18	25
5	22	16	17	32
6	19	21	16	24
7	17	19	21	28
8	19	15	23	26
9	27	16	14	27
10	24	21	16	24
11	13	19	24	30
12	22	16	26	23
13	19	22	19	36
14	24	18	18	29
15	17	19	20	29
Mean	**19.93**	**18.73**	**20.13**	**28.13**
S.D	**3.52**	**2.22**	**3.78**	**3.46**
C.V (%)	**17.66**	**11.85**	**18.78**	**12.30**

Cation Exchange Capacity: Cation exchange capacity in the topsoils is higher under the adjoining native rainforest than under the isolated tree stands. This is as expected since there is a higher build-up of organic matter in the topsoils under the adjoining rainforest than under the isolated tree stands. The cation exchange capacity of tropical soils such as occur in the study area largely depends on the organic fraction of the soil since their clay minerals naturally have a low capacity to adsorb nutrient cations (Nye and Greenland, 1960; Aweto, 1978).

Table 4.32 shows the mean cation exchange capacity values for the topsoils of the sample sites. The avocado pear tree stands, mango tree stands, Indian almond tree stands and the adjoining rainforest respectively have the mean cation exchange capacity values of 7.17, 7.56, 7.75 and 14.4 meq/100g of soil. The mean cation exchange capacity value for the adjoining rainforest is higher than those of the isolated tree stands, while the lowest mean value was observed under the avocado pear stands. Among the isolated tree stands, the mean cation exchange capacity values are similar. This is probably due to the immobilization of nutrient cations in the standing crop of the isolated tree stands as earlier referred to. However, with respect to nutrient cycling under the isolated tree stands, it could be deduced that the lower CEC under the isolated tree stands indicates that the returns of nutrient cations to the soil is higher under the adjoining rainforest than under the isolated tree stands.

Table 4.33 shows the mean cation exchange capacity values for the subsoils of the different sample sites. The mean cation exchange capacity values for the avocado pear, mango, Indian almond and adjoining rainforest are 3.87, 3.97, 3.98 and 5.73 meq/100g of soil respectively. The mean cation exchange capacity values of the subsoils are lower in the soils under the isolated tree stands than under the adjoining rainforest. However, the cation exchange capacity of the topsoils is generally higher under the different sample site than in the subsoils. This re-emphasizes that the topsoils contain higher organic matter than the subsoils.

Although the mean clay contents of the subsoils are higher than those of the topsoils, the latter has higher CEC than the former. This reveals that the organic matter content of soil contribute more to CEC of the soil than the clay content of soil (Marx *et al.*, 1999).

Table 4.32: Cation exchange capacity values of the topsoil in milliequivalents per 100g of soil (meq/100g of soil)

Sample sites	**0 - 15cm soil depth**			
	Avocado pear	Mango	Indian almond	Adjoining rainforest
1	7.66	7.92	7.98	13.59
2	6.25	7.77	8.00	14.51
3	7.23	6.59	7.69	11.17
4	7.24	7.57	7.97	14.55
5	7.63	7.79	7.15	11.54
6	6.79	8.02	7.98	15.39
7	7.03	7.31	7.62	14.93
8	7.50	7.84	7.65	15.33
9	7.92	7.29	7.67	15.47
10	7.23	7.76	7.87	16.13
11	7.21	7.90	7.17	11.14
12	6.66	6.73	8.13	15.82
13	7.01	7.18	7.20	15.19
14	6.60	7.74	8.13	14.73
15	7.51	7.98	8.02	16.66
Mean	**7.17**	**7.56**	**7.75**	**14.41**
S.D	**0.45**	**0.45**	**0.34**	**1.77**
C.V (%)	**6.28**	**5.95**	**4.39**	**12.28**

Table 4.33: Cation exchange capacity values of the subsoil in milliequivalents per 100g of soil (meq/100g of soil)

Sample sites	**15cm – 30cm soil depth**			
	Avocado pear	Mango	Indian almond	Adjoining rainforest
1	3.96	4.09	3.94	5.84
2	3.64	4.09	4.03	7.06
3	4.27	3.84	3.84	5.01
4	4.06	3.97	4.06	4.56
5	4.17	3.91	3.62	6.75
6	3.92	3.95	4.18	4.70
7	3.69	4.16	4.11	4.83
8	3.97	3.86	3.88	4.88
9	3.83	3.86	4.02	5.77
10	4.04	3.95	3.78	5.99
11	3.94	4.03	3.64	4.19
12	3.73	3.69	3.89	6.37
13	3.67	4.01	4.04	6.03
14	3.64	3.90	4.36	7.20
15	3.57	4.17	4.25	6.74
Mean	**3.87**	**3.97**	**3.98**	**5.73**
S.D	**0.21**	**0.13**	**0.21**	**0.98**
C.V (%)	**5.43**	**3.28**	**5.28**	**17.10**

Base Saturation Percentage:

The proportion of CEC which is occupied by cations other than hydrogen (H) varies amongst the isolated tree stands and the adjoining rainforest, as well as between the two soil layers. Topsoils have higher base saturation than the subsoils, thus shows that the percentage of hydrogen and aluminum saturation is lower in the topsoils. Saturation percentage was higher in the soil under the adjoining rainforest than that under the isolated tree stands.

Table 4.34 shows the percentage values of base saturations for the topsoils and subsoils under the isolated tree stands and the adjoining rainforest. In the topsoils, the mean values for base saturation under avocado pear, mango, Indian almond and Adjoining rainforest are 83.19, 84.07, 84.48 and 91.54% respectively.

Although the mean saturation percentages are lower among the isolated tree stands than the adjoining rainforest, the saturation of hydrogen and aluminum underneath indicate that the soils under the isolated tree stands can be very productive to support effective growth and development of tree crops in the rainforest ecosystem. With respect to the subsoils, the mean values for base saturation under avocado pear, mango, Indian almond and Adjoining rainforest are 68.93, 69.71, 69.74 and 78.45% respectively.

The percentage of hydrogen and aluminum saturation is therefore higher with the isolated tree stands than the adjoining rainforest. However, hydrogen and aluminum saturation percentages are higher in the subsoils than in the topsoils, which could be as a result of higher concentrations of acid in the subsoil than in the topsoil layers respectively.

Table 4.34: Percentage values of base saturations for the topsoils and subsoils

Sample Sites	**Saturation (%) for Topsoils**				**Saturation (%) for Subsoils**			
	Avocado pear	Mango	Indian almond	Adjoining rainforest	Avocado pear	Mango	Indian almond	Adjoining rainforest
1	84.33	84.85	84.96	91.17	69.70	70.66	69.54	79.45
2	80.80	84.56	85.00	91.73	67.03	70.66	70.22	83.00
3	83.40	81.79	84.40	89.26	71.90	68.75	68.75	76.05
4	83.43	84.15	84.94	91.75	70.44	69.77	70.44	73.68
5	84.27	84.60	83.22	89.60	71.22	69.31	66.85	82.22
6	82.33	85.04	84.96	92.20	69.39	69.62	71.29	74.47
7	82.93	83.58	84.25	91.96	67.48	71.15	70.80	75.16
8	84.00	84.69	84.31	92.17	69.77	68.91	69.07	75.41
9	84.85	83.54	84.36	92.24	68.67	68.91	70.15	79.20
10	83.40	84.54	84.73	92.56	70.30	69.62	68.25	79.97
11	83.36	84.81	83.26	89.23	69.54	70.22	67.03	71.36
12	81.98	82.17	85.24	92.42	67.83	67.48	69.15	81.16
13	82.88	83.29	83.33	92.10	67.30	70.08	70.30	80.10
14	81.82	84.50	85.24	91.85	67.03	69.23	72.48	83.33
15	84.02	84.96	85.04	92.80	66.39	71.22	71.77	82.20
Mean	**83.19**	**84.07**	**84.48**	**91.54**	**68.93**	**69.71**	**69.74**	**78.45**

Soil pH: One would expect a rise in the level of soil pH in the topsoil as a result of build-up of exchangeable nutrient bases through nutrients return to the soil. Table 4.35 shows the mean pH values of the topsoils of the isolated tree stands and their adjoining rainforests. The mean pH values for Avocado pear, mango, Indian almond and adjoining rainforest areas are 6.10, 5.53, 5.77 and 6.25 respectively. The figures reveal that there are variations in the soil pH level amongst the isolated tree stands and the adjoining rainforest, while the value is higher in the adjoining rainforest.

While the sample sites for the isolated tree stands are made of single tree species, the adjoining rainforest comprises many tree species which may exert different effects on the pH levels of the soils underneath their stands. It seems that under the adjoining rainforest condition, the higher levels of base cations in the topsoil help to raise the level of soil pH. Hence the adjoining rainforest areas have relatively higher pH values as compared to those of the isolated tree stands. Generally, the pH values of the topsoils as observed show that the acid level of the different sample sites ranges from moderately acidic (5.2 – 6.0) to slightly acidic (6.1 – 6.5), with soils under Indian almond and mango tree stands being more acidic than the Avocado pear stands and the adjoining rainforest areas respectively.

Table 4.36 shows the pH values of the subsoils under the different sample sites. Generally, the pH values of the subsoils are lower than those of the topsoils. The mean pH values for Avocado pear, mango, Indian almond and adjoining rainforest are 5.71, 4.96, 5.21 and 5.76 respectively. The pH values decreases with depth mainly because the concentrations of base cations decreased with depth down the soil profile.

The pH values of the subsoils under the isolated tree stands and the adjoining rainforest ranged between moderately acidic (5.2 -6.0) to strongly acidic (≤ 5.1), with soil under mango tree stands being more acidic than the soils under the rest sample sites. However, results of the ANOVA test (Table 4.37) revealed that the observed variations in the pH values of the topsoils under the isolated tree stands and the adjoining rainforest are significant at the 5% confidence level.

Table 4.35: pH values of the topsoils

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	5.1	5.1	6.0	6.3
2	6.5	5.2	5.6	5.1
3	6.5	5.2	5.1	5.2
4	6.3	5.0	5.8	7.1
5	5.2	5.2	5.3	5.8
6	6.5	6.0	6.4	6.7
7	6.5	6.2	6.1	6.2
8	6.4	5.8	5.6	6.0
9	6.5	6.0	5.7	7.0
10	5.4	6.1	6.3	5.6
11	6.2	5.2	5.8	6.2
12	6.5	5.3	5.7	7.0
13	6.5	5.1	5.5	7.3
14	5.8	5.7	6.1	6.2
15	5.6	5.9	5.6	6.1
Mean	**6.10**	**5.53**	**5.77**	**6.25**

Table 4.36: pH values of the subsoils

Sample sites	Avocado pear (*Persea gratissima*)	Mango (*Mangifera indica*)	Indian Almond (*Terminalia cattapa*)	Adjoining Rainforest
1	5.0	5.0	4.8	6.0
2	6.4	4.0	5.4	4.4
3	6.2	4.9	4.8	4.7
4	5.1	4.8	5.4	6.6
5	5.0	5.0	5.0	5.6
6	6.4	4.8	5.0	6.1
7	6.2	4.1	5.2	6.0
8	6.2	4.2	5.2	5.6
9	6.5	4.7	5.5	6.3
10	5.0	4.9	4.9	5.4
11	5.7	4.6	5.6	5.4
12	5.9	5.1	5.5	6.2
13	5.6	5.1	4.9	6.7
14	5.3	4.9	5.8	5.8
15	5.2	4.3	5.1	5.6
Mean	**5.71**	**4.96**	**5.21**	**5.76**

Result of the Analysis of Variance for the pH content of the subsoil (Table 4.38) shows that the calculated F-value of 15.531 is greater than the critical table F-value of 2.84. There is therefore a significant difference in the pH values of the subsoil layer amongst the isolated tree stands and the adjoining rainforest.

From table 4.37, the F-values obtained were all greater than the critical table values. Therefore, the differences in the soil variables are all significant at the 5% confidence levels. However, results of the multiple comparisons of the means using the Least Square Difference (LSD) test (appendix 4.37) shows that the mean differences are significant between the pairs of Avocado pear and mango, Avocado pear and Indian almond, mango and Indian almond, Mango and adjoining rainforest, Indian almond and adjoining rainforest respectively.

However, the pairs of comparisons where the mean differences in the soil characteristics are significant are as shown in appendixes 4.6 – 4.33 respectively. These results therefore revealed that the different isolated tree stands and the adjoining rainforest do not have the same nutrient compositions in both the topsoil and subsoil layers respectively. Although the concentrations of some of the soil properties such as the particle size compositions, calcium, magnesium, potassium, CEC and soil pH have close similarities in both the isolated tree stands and the adjoining rainforest. This is as to be expected because the different sample sites are made of different tree species; the species of the isolated tree stands are not contained in the adjoining rainforest; the vegetation characteristics of the tree stands which enhance organic matter accumulation in the topsoil vary, and the isolated tree stands have peculiar crown architectures which differ from that of the adjoining rainforest.

Table 4.37: Results of one-way analysis of variance amongst avocado pear, mango, Indian almond and adjoining rainforest: topsoil parameters

Soil parameters	Groups	Sum of squares	d/f	Mean square	F	Table F	Level of significance
Porosity	Between	594.854	3	198.283	18.487	2.84	0.05
	Within	600.620	56	100.725			
	Total	1195.470	59				
Bulk density	Between	0.417	3	0.139	18.457	2.84	0.05
	Within	0.421	56	0.008			
	Total	0.838	59				
Water holding capacity	Between	479.723	3	159.908	24.933	2.84	0.05
	Within	359.151	56	6.413			
	Total	838.874	59				
Sand	Between	163.829	3	54.610	13.271	2.84	0.05
	Within	230.445	56	4.115			
	Total	394.274	59				
Silt	Between	338.982	3	112.994	42.295	2.84	0.05
	Within	149.608	56	2.672			
	Total	488.590	59				
Clay	Between	48.403	3	16.134	7.071	2.84	0.05
	Within	127.785	56	2.282			
	Total	176.188	59				
Organic matter	Between	38.857	3	12.952	41.718	2.84	0.05
	Within	17.387	56	0.310			
	Total	56.244	59				
Organic carbon	Between	13.143	3	4.381	42.342	2.84	0.05
	Within	5.794	56	0.103			
	Total	18.937	59				
Total nitrogen	Between	0.175	3	0.058	9.340	2.84	0.05
	Within	0.349	56	0.006			
	Total	0.524	59				
Available phosphorus	Between	97.009	3	32.336	4.045	2.84	0.05
	Within	447.684	56	7.994			
	Total	544.693	59				
Potassium	Between	35882.983	3	11960.994	60.073	2.84	0.05
	Within	11150.000	56	199.107			
	Total	47032.983	59				
Calcium	Between	10225671	3	3408556.906	95.943	2.84	0.05
	Within	1989504	56	35526.862			
	Total	12215175	59				
Magnesium	Between	564774.3	3	188258.106	99.604	2.84	0.05
	Within	105843.3	56	1890.060			
	Total	670617.7	59				
Sodium	Between	15088.450	3	5029.483	55.464	2.84	0.05
	Within	5078.133	56	90.681			
	Total	20166.583	59				
C.E.C	Between	541.247	3	180.416	196.783	2.84	0.05
	Within	51.342	56	0.917			
	Total	592.589	59				
pH	Between	4.716	3	1.572	6.039	2.84	0.05
	Within	14.580	56	0.260			
	Total	19.296	59				

Significant at F > critical table F (2.84) at the 0.05 level

Table 4.38: results of one-way analysis of variance amongst avocado pear, mango, Indian almond and adjoining rainforest: subsoil parameters

Soil parameters	Groups	Sum of squares	d/f	Mean square	F	Table F	Level of significance
Porosity	Between	194.742	3	64.914	4.024	2.84	0.05
	Within	903.441	56	16.133			
	Total	1098.183	59				
Bulk density	Between	0.120	3	0.040	3.559	2.84	0.05
	Within	0.631	56	0.011			
	Total	0.752	59				
Water holding capacity	Between	645.953	3	215.318	31.417	2.84	0.05
	Within	383.795	56	6.853			
	Total	1029.747	59				
Sand	Between	40.616	3	13.539	4.855	2.84	0.05
	Within	156.154	56	2.788			
	Total	196.770	59				
Silt	Between	59.208	3	19.736	9.154	2.84	0.05
	Within	120.858	56	2.158			
	Total	180.066	59				
Clay	Between	112.248	3	37.416	7.380	2.84	0.05
	Within	283.914	56	5.070			
	Total	396.162	59				
Organic matter	Between	26.241	3	8.747	48.592	2.84	0.05
	Within	10.080	56	0.180			
	Total	36.321	59				
Organic carbon	Between	8.837	3	2.946	48.380	2.84	0.05
	Within	3.410	56	0.061			
	Total	12.246	59				
Total nitrogen	Between	0.062	3	0.021	12.240	2.84	0.05
	Within	0.095	56	0.002			
	Total	0.157	59				
Available phosphorus	Between	20.226	3	6.742	3.625	2.84	0.05
	Within	104.153	56	1.860			
	Total	124.379	59				
Potassium	Between	1522.200	3	507.400	14.284	2.84	0.05
	Within	1989.200	56	35.521			
	Total	3511.400	59				
Calcium	Between	374673.6	3	124891.217	19.973	2.84	0.05
	Within	350176.0	56	6253.143			
	Total	724849.6	59				
Magnesium	Between	107435.4	3	35811.794	26.323	2.84	0.05
	Within	76185.867	56	1360.462			
	Total	183621.3	59				
Sodium	Between	836.400	3	278.800	25.623	2.84	0.05
	Within	609.333	56	10.881			
	Total	1445.733	59				
C.E.C	Between	36.133	3	12.044	45.254	2.84	0.05
	Within	14.904	56	0.266			
	Total	51.037	59				
pH	Between	11.275	3	3.758	15.531	2.84	0.05
	Within	13.552	56	0.242			
	Total	24.827	59				

F > critical table F (2.84) at the 0.05 level

Table 4.38 presents the summary of results obtained from the one-way analysis of variance statistics for subsoil parameters amongst the isolated tree stands and the adjoining rainforest. The results as shown indicate that the soil parameters investigated were all significantly different between the isolated tree stands and the adjoining rainforest, and with close similarities in the subsoils amongst the isolated tree stands. The F-values obtained for all the soil properties are greater than the critical table values. Therefore, the differences in the soil variables were all significant at the 5% confidence levels. This means that the sample sites have variant soil characteristics.

However, results of the post hoc analysis using the LSD test show that the mean differences in the compositions of the entire soil variable are significant between the isolated tree stands and the adjoining rainforest. While the mean differences are not significant among the isolated tree stands for the compositions of total porosity, bulk density, water holding capacity, sand, clay, calcium, magnesium, potassium, phosphorus, sodium and CEC, significant differences in the mean compositions of some variables like silt, organic carbon, organic matter and pH were observed amongst the isolated tree stands respectively.

4.4 Discussions

The characteristics of tree stands varied amongst the isolated tree stands and the adjoining rainforest. Trees in the adjoining rainforest are taller than the isolated tree stands. However, amongst the isolated tree stands, tree heights also varied. Taller tree stands have been observed to spread their litterfall outside tree canopies. The implication of litterfall farther away from tree stands may lead to a reduced nutrient returns under some of the tree stands because, litterfall contribute to organic matter in the soil. Soil organic matter not only influences the amount of nutrients that accumulate under tree stands but also soil physical attributes such as porosity, water holding capacity and soil crumb structure which have a direct bearing on the level of soil fertility (Aweto, 1978). Also, the addition of organic matter to the soil enhances the aggregation of soil particles thus improving the soil porosity. Therefore, the role of organic matter content in the build-up of soil nutrients under tree stands appears crucial.

Soil properties under the isolated tree stands and the adjoining rainforest varied. Results of studies by Ekanade (1989, 1990) also observed a significant variation in soil properties under cocoa and kola interplanted. Also, soil pH, organic matter, available phosphorus, calcium, potassium and magnesium have their greatest mean values in the topsoil.

The findings in this study have revealed that the soils under the isolated tree stands and adjoining rainforests varied in terms of textural composition. Under the isolated tree stand and the adjoining rainforest, sand contents are higher than that of silt and clay at both the topsoils and subsoils respectively. The pattern is such that the proportions of sand contents are higher than that of silt, while silt contents are higher than clay contents. Generally, clay contents are higher in the subsoils than in the topsoils. However, Indian almond stands for instance, tends to have more clay in the topsoil underneath than the other isolated tree stands, but has the lowest clay than the other isolated tree stands in the subsoils.

As will be expected, some of the observed variations in the level of nutrients and water holding capacity of the soils may be attributed partly to the variations in the clay content of the soil. The adjoining rainforest has the highest capacity to hold water than the isolated tree stands. However, amongst the isolated tree stands, the soil under avocado pear has the lowest capacity to hold water. Therefore, it can possibly be deduced that shade cast on the soil owing to wider crown area which shields the soil, affects the soil capacity to hold water.

Total nitrogen is higher under the adjoining rainforest than under the isolated tree stands and this is similar to the observed pattern of soil organic matter content. This is as it should be since soil organic matter is the chief ‘store’ of soil nitrogen (Aweto, 1978; Vitousek and Sanford, 1986). There is no appreciable build-up of total nitrogen in the subsoils of the isolated tree stands and those of the adjoining rainforests. Therefore it emphasizes that total nitrogen accumulation under tree stands is confined to the topsoils as in the case of organic matter. However, the results of ANOVA test (Table 4.38) revealed that the observed differences in the nitrogen content of the subsoils under the isolated tree stands and the adjoining rainforest are significant at the 5% confidence level.

Generally, the concentrations of exchangeable cations are higher in the topsoils than in the subsoils. The pattern of variation shown by each of the four cations is the same for magnesium, potassium and sodium (adjoining rainforest > Indian almond > mango > Avocado pear); but different from that of calcium which is Indian almond > mango > Avocado pear > adjoining rainforest respectively.

Although the mean clay contents of the subsoils are higher than those of the topsoils, the latter has higher CEC than the former. This implies that the organic matter content of the soil is more important than the clay content in contributing to the CEC of the soil. The mean cation exchange capacity values of the subsoils are lower in the soils under the isolated tree stands than under the adjoining rainforest. However, the cation exchange capacity of the soils under the isolated tree stands and the adjoining rainforest is generally higher in the topsoils than in the subsoils. This re-emphasizes that the topsoils contain higher organic matter than the subsoils.

Also, topsoils have higher base saturation than the subsoils, thus shows that the percentage of hydrogen and aluminum saturation is lower in the topsoils. Although the mean saturation percentages are lower among the isolated tree stands than the adjoining rainforest, the saturation of hydrogen and aluminum underneath indicate that the soils under the isolated tree stands can be very productive to support effective growth and development of tree crops in the rainforest ecosystem. This is because soils could still be productive up to 20% saturation of hydrogen (Chapman, 1976; Marx *et al.*, 1999).

CHAPTER FIVE

NUTRIENT RETURNS TO SOIL THROUGH LITTERFALL, THROUGHFALL AND STEMFLOW UNDER TREE STANDS

5.1 INTRODUCTION

Litterfall and rainwash from aboveground tree stands help in the transfer of nutrient elements to the soil underneath the tree stands. However, unlike nutrient returns in litterfall, nutrients input to the soil through rainwash are immediately available for plants uptake (Eaton *et al,* 1973). This chapter is concerned with the concentrations and returns of nutrients to the soils under the isolated tree stands and the adjoining rainforest areas through stemflow, throughfall and litterfall. It emphasised the variations in both the concentrations and returns of nutrients amongst the isolated tree stands and the adjoining rainforest; compared the nutrient compositions of rainwash with that from the incident rainfall; compared the returns of nutrients to the soil between litterfall, stemflow and throughfall; examined the seasonal patterns of nutrient flux through stemflow, throughfall and litterfall to the soil as aspects of nutrient returns to the soil in nutrient cycling; and determined the relationships between litter production and nutrient returns through litterfall.

5.2 LITTERFALL AND NUTRIENTS RETURN TO THE SOIL

Litter production, nutrient concentrations and returns of nutrient elements to the soil through litterfall vary amongst the isolated tree stands, as well as with the seasons of the year.

5.2.1 Litter Production

The quantity of litter produced varied amongst the isolated tree stands and the adjoining rainforest. The mean annual litter production for the Indian almond, mango, avocado pear and adjoining rainforest are 83.04, 76.53, 60.23 and 77.31 g/m² respectively (Table 5.1).

Table 5.1: Monthly litter production in g/m²

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	30.02	51.32	50.62	128.40
Mar	49.01	53.54	45.40	148.62
Apr	62.13	69.64	41.49	62.95
May	89.33	68.68	34.12	50.16
Jun	82.10	73.01	40.02	48.71
Jul	99.18	88.94	41.03	40.47
Aug	142.00	105.41	63.26	49.20
Sep	147.16	112.02	68.62	50.28
Oct	186.34	124.72	69.86	54.61
Nov	42.16	68.42	80.38	82.11
Dec	38.41	50.20	94.96	104.92
Jan	28.62	52.41	92.94	107.24
Mean	**83.04**	**76.53**	**60.23**	**77.31**
S.D	**51.87**	**25.58**	**21.27**	**36.35**
C.V (%)	**62.46**	**33.43**	**35.32**	**47.02**

Among the isolated tree stands, litter production was highest in Indian almond and lowest in Avocado pear stands. However, in comparison with the adjoining rainforest, litter production was lower in the stands of mango and avocado pear than the adjoining rainforest. The much lower litter production observed in the Avocado pear stands could be attributed to the size of tree crown architecture, while the close canopy influence in the adjoining rainforest may have enhanced the amount of litter produced under the forest cover. The observed differences in litter production amongst the isolated tree stands and the adjoining rainforest were significant at the 5% confidence level when tested with the one-way analysis of variance statistics (Table 5.2), except for the difference in the mean litter production between mango and the adjoining rainforest as observed from the post-hoc analysis using the LSD test (appendix 5.1).

Table 5.2: Results of one-way analysis of variance amongst the isolated tree stands and the adjoining rainforest: Litter production

Vegetation characteristics	**Groups**	**Sum of squares**	**d/f**	**Mean square**	**F**	**Table F**	**Level of significance**
Litter production	Between	4048.358	3	1349.453	3.85	2.84	0.05
	Within	21018.14	44	477.69			
	Total	25066.50	47				

Significant at F > critical table F (2.84) at the 0.05 level

The amount of litter produced by the isolated trees and the adjoining rainforest varies seasonally, and obviously with the phonological changes which occurred in the different tree species. While litter production by Indian almond and Mango trees was higher between July and October, it was higher in Avocado pear between August and January, and the adjoining rainforest was between November and March (Fig. 5.1).

The pattern of seasonal variation in the production of litter in the adjoining rainforest is similar to the observed patterns in studies by Muoghalu *et al.* (1993) in a Nigerian rainforest; and Hermansah et al (2002) in the tropical rainforest of Western Sumatra, Indonesia, since litter production is highest in the dry season months; but differ from the study by Pragasan and Parthasarathy (2005) in the tropical dry evergreen forests of south Indian. It could therefore be deduced that the seasonal trends in litter production between Indian almond and mango tree stands are similar, while that of the Avocado pear stands and the adjoining rainforest are also similar. Although litter production in the adjoining rainforest is higher than that by the Avocado pear stands, the pattern of litter production is quite similar throughout the months of the year. However, Indian almond tree stands which produced the smallest amount of litter in the dry season months also produced the highest litter in the rainy months, with peak in the month of October.

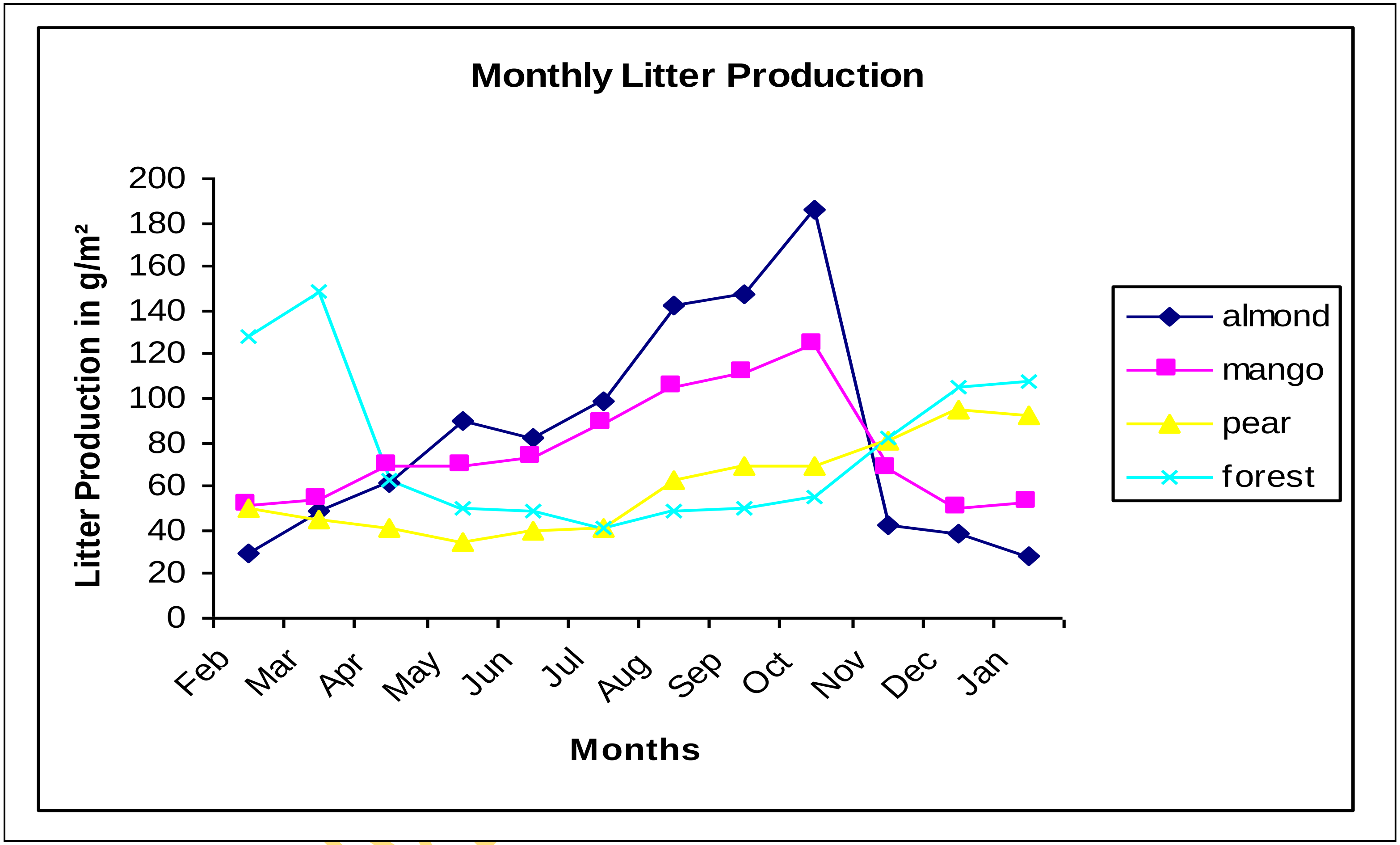


Fig. 5.1: Seasonal Variations in Litter Production

5.2.2 Nutrient Concentrations in Litterfall

The concentrations of nutrient elements in litterfall vary amongst the isolated tree stands and the adjoining rainforest, as well as the seasons of the year.

Table 5.3 shows the mean annual concentrations of nutrient elements in litterfall, while appendices 5.2 – 5.7 present the monthly concentrations of the different nutrient elements for the isolated tree stands and the adjoining rainforest respectively. Except for the concentrations of potassium, nutrient elements are all higher in the adjoining rainforest than in the isolated tree stands. Generally, the concentrations of Ca, N and K are higher than those of Mg, P and Na respectively. The results of the concentration of nutrient elements in the adjoining rainforest which is higher with Ca, N and K than those of Mg, P and Na, corroborate with findings in the studies by Nye and Greenland (1960) where the concentrations of N, P, K, Ca and Mg are 19, 0.7, 6.5, 19.6 and 4.3 mg/g respectively; and Bernhard-Reversat (1972) where the concentrations of N, P, K, Ca and Mg are 14, 0.5, 4.9, 13.6 and 3.2 mg/g respectively.

Table 5.3: Mean concentrations of nutrient elements in litterfall in mg/g

Nutrient elements	Sites			
	Indian almond *(Terminalia cattapa)*	Mango *(Mangifera indica)*	Avocado pear *(Persea gratissima)*	Adjoining rainforest
Nitrogen	5.87	4.78	4.51	10.69
Phosphorus	0.66	0.60	0.70	0.72
Potassium	4.87	3.74	3.43	3.69
Calcium	7.72	7.14	9.00	9.53
Sodium	0.41	0.34	0.51	0.53
Magnesium	2.27	1.64	3.13	3.18

5.2.2 TESTING OF HYPOTHESIS

H1: The concentrations and returns of nutrient elements to the soil through litterfall and rainwash vary amongst the isolated tree stands and the adjoining rainforest.

In order to test the hypothesis, the one-way analysis of variance statistics was employed to examine the differences in the concentrations of nutrient elements in litterfall amongst the isolated tree stands and the adjoining rainforest respectively. The results of the analyses are presented in table 5.4. The results revealed that apart from phosphorus and potassium, the concentrations of the nutrient elements are significantly different at the 5% confidence levels. Therefore, the stated hypothesis is accepted.

Multiple comparisons of the differences in the mean concentrations of the nutrient elements using the LSD test (appendix 5.9) revealed that the mean differences in nitrogen concentrations are between the pairs of Indian almond and adjoining rainforest, mango and adjoining rainforest as well as avocado pear and adjoining rainforest respectively. No significant difference was observed in the pairs of means amongst the isolated tree stands.

The mean differences in the concentrations of calcium are between the pairs of Indian almond and adjoining rainforest, mango and avocado pear, and between mango and adjoining rainforest (appendix 5.10). This shows that there is no significant difference in the concentrations of calcium between the avocado pear stands and the adjoining rainforest. The mean differences in the concentrations of sodium are similar to that of the concentrations of calcium. The observed mean concentrations were different between the pairs of Indian almond and adjoining rainforest, mango and avocado pear, and between mango and adjoining rainforest (appendix 5.11). There was no observed difference in the concentrations of sodium between avocado pear and adjoining rainforest. The mean differences in the concentrations of magnesium (appendix 5.12) are between the pairs of Indian almond and mango, Indian almond and avocado pear, Indian almond and adjoining rainforest, mango and avocado pear, mango and adjoining rainforest. However, avocado pear and adjoining rainforest are similar in the concentration of magnesium. Generally, the concentrations of P and K are not significant thus, multiple comparison of the means were not carried out.

Table 5.4: Results of one-way analysis of variance for nutrient concentrations in litterfall amongst avocado pear, mango, Indian almond and adjoining rainforest

Nutrient Element	Groups	Sum of squares	d/f	Mean square	F	Sig.
Nitrogen	Between	298.207	3	99.402	23.785	0.001
	Within	183.884	44	4.179		
	Total	482.091	47			
Phosphorus	Between	0.091	3	0.030	1.007	0.399
	Within	1.323	44	0.030		
	Total	1.414	47			
Potassium	Between	14.599	3	4.866	1.593	0.205
	Within	134.397	44	3.054		
	Total	148.996	47			
Calcium	Between	43.905	3	14.635	4.260	0.010
	Within	151.176	44	3.436		
	Total	195.080	47			
Sodium	Between	0.291	3	0.097	4.636	0.007
	Within	0.919	44	0.021		
	Total	1.210	47			
Magnesium	Between	19.729	3	6.576	14.493	0.001
	Within	19.966	44	0.454		
	Total	39.695	47			

5.2.3 pH Values in Litter

The monthly pH value of litter varies significantly amongst the isolated tree stands and the adjoining rainforest at the 5% confidence level (appendix 5.13). The mean annual pH values for the Indian almond, mango, avocado pear and adjoining rainforest are 4.53, 4.98, 5.08 and 5.18 respectively. This indicates that pH in the adjoining rainforest is higher than those of the isolated tree stands. However, among the isolated tree stands, the mean pH value for avocado pear litter is highest. Therefore, the acid content of litter is higher in the stands of Indian almond and mango than in avocado pear stands and the adjoining rainforest respectively.

5.2.4 Returns of Nutrient Elements to the Soil through Litterfall

The returns of nutrient elements to the soil through litterfall vary amongst the isolated tree stands and the adjoining rainforest, as well as the seasons of the year.

Table 5.5 shows the mean annual returns of nutrient elements to the soil through litterfall, while appendices 5.14 – 5.19 present the monthly returns of the different nutrient elements to the soil via litterfall, from the isolated tree stands and the adjoining rainforest respectively. Apart from the returns of phosphorus and potassium which are higher in the stands of Indian almond, nutrient elements returned to the soil are all higher in the adjoining rainforest than in the isolated tree stands. Generally, the returns of Ca, N and K are higher than those of Mg, P and Na. Results of the returns of nutrient elements in the adjoining rainforest which is higher with Ca, N and K than those of Mg, P and Na, corroborate with findings in the study by Muoghalu *et al.* (1993) where the returns of N, P, K, Ca and Mg are 6.6, 4.0, 4.5, 9.7 and 1.5 respectively.

Table 5.5: Mean annual returns of nutrient elements via litterfall in kg/ha

Nutrient elements	Sites			
	Indian almond *(Terminalia cattapa)*	Mango *(Mangifera indica)*	Avocado pear *(Persea gratissima)*	Adjoining rainforest
Nitrogen	5.73	3.43	2.42	9.08
Phosphorus	0.65	0.45	0.42	0.60
Potassium	4.92	2.64	2.14	3.39
Calcium	7.50	5.22	5.37	7.81
Sodium	0.41	0.25	0.31	0.49
Magnesium	2.22	1.17	1.87	2.57

5.2.5 TESTING OF HYPOTHESIS

H1: The concentrations and returns of nutrient elements to the soil through litterfall and rainwash vary amongst the isolated tree stands and the adjoining rainforest.

In order to test the hypothesis, the one-way analysis of variance statistics was employed to examine the differences in the returns of nutrient elements to the soil through litterfall amongst the isolated tree stands and the adjoining rainforest respectively. The results of the analyses are presented in table 5.6. The results revealed that the returns of N, K, Na and Mg are significantly different at the 5% confidence levels. Therefore, the stated hypothesis is accepted.

Multiple comparisons of the differences in the mean returns of N, K, Na and Mg to the soil using the LSD test (appendices 5.20 – 5.23) revealed the pairs of the mean where the observed differences are. The mean differences in nitrogen returns are between the pairs of Indian almond and avocado pear, Indian almond and adjoining rainforest, mango and adjoining rainforest, and between avocado pear and adjoining rainforest respectively.

Table 5.6: Results of one-way analysis of variance for nutrient returns via litterfall to the soils under avocado pear, mango, Indian almond and adjoining rainforest

Nutrient Element	Groups	Sum of squares	d/f	Mean square	F	Sig.
Nitrogen	Between	312.296	3	104.099	6.587	0.001
	Within	695.388	44	15.804		
	Total	1007.684	47			
Phosphorus	Between	0.449	3	0.150	1.096	0.361
	Within	6.004	44	0.136		
	Total	6.452	47			
Potassium	Between	72.860	3	24.287	3.283	0.042
	Within	325.472	44	7.397		
	Total	378.332	47			
Calcium	Between	67.495	3	22.498	1.244	0.305
	Within	795.957	44	18.090		
	Total	863.452	47			
Sodium	Between	2.405	3	.802	12.339	0.001
	Within	2.861	44	.065		
	Total	3.266	47			
Magnesium	Between	15.838	3	5.279	3.273	0.044
	Within	70.977	44	1.613		
	Total	83.815	47			

5.2.6 Seasonal Variations in Nutrients Return to the Soil through Litterfall

The trend in the returns of nutrient elements to the soil through litterfall amongst the isolated tree stands and the adjoining rainforest varies with the seasons of the year (Fig 5.2 – 5.7). Indian almond stands returned the highest nitrogen in October, mango stands returned the highest nitrogen in March, and avocado pear stands returned the highest nitrogen in May, while the adjoining rainforest returned the highest nitrogen in the month of March (Fig. 5.2).

The seasonal pattern of nitrogen return shows that the Indian almond and avocado pear return more nitrogen to the soil within the rainy months, while the adjoining rainforest and mango tree stands returned more nitrogen in the month of March when rainy season begins in this study area.

Indian almond tree stands returned the highest phosphorus to the soil in the month of October, mango stands returned the highest phosphorus in March, and avocado pear stands returned the highest phosphorus in January, while adjoining rainforest returned the highest phosphorus in the month of March respectively. This shows a marked variation in the return of phosphorus through litterfall amongst the isolated tree stands and the adjoining rainforest (Fig. 5.3).

The seasonal pattern of phosphorus return shows that while the adjoining rainforest and mango tree stands share similarity in the return of phosphorus (that is highest amount in March), Indian almond and avocado pear stands returned the highest amount of phosphorus to the soil in the month of October and January respectively. Fig 5.4 shows the seasonal pattern of potassium return to the soil through litterfall. Indian almond tree stands returned the highest amount of potassium to the soil in the process of nutrient cycling. As could be observed, Indian almond, mango, avocado pear and adjoining rainforest returned the highest potassium in October, April, January and February respectively. The seasonal pattern of potassium return therefore shows that the Indian almond and mango tree stands return more potassium in the rainy season than in the dry season, while the avocado pear and adjoining rainforest return more potassium during the dry season.

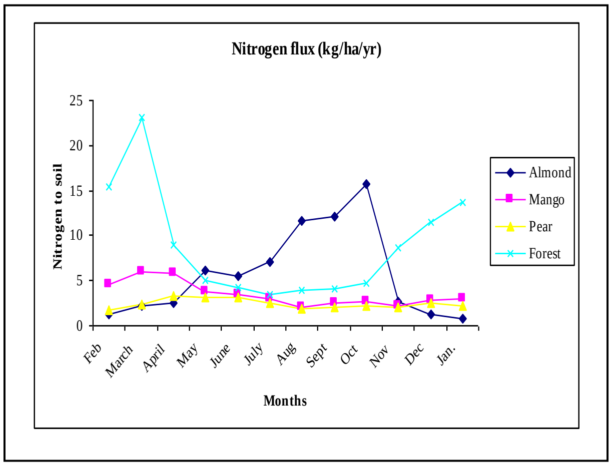


Fig 5.2: Seasonal Variations in Nitrogen Flux

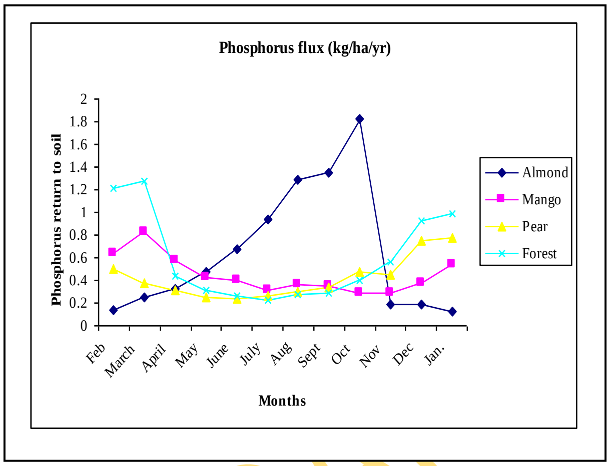


Fig 5.3: Seasonal Variations in Phosphorus Flux

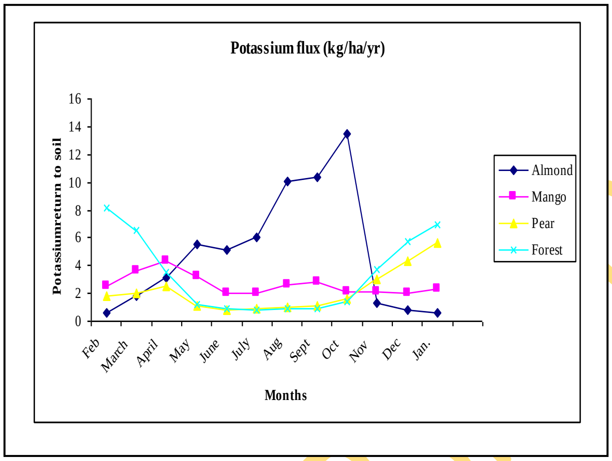


Fig 5.4: Seasonal Variations in Potassium Flux

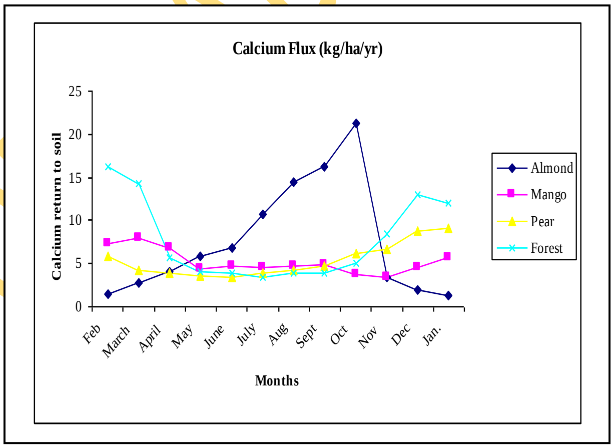


Fig 5.5: Seasonal Variations in Calcium Flux

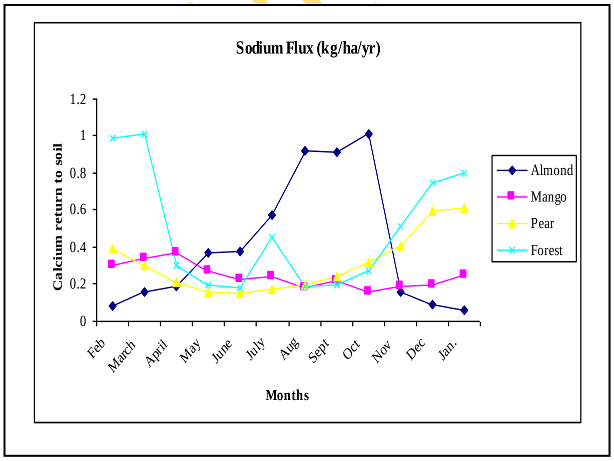


Fig 5.6: Seasonal Variations in Sodium Flux

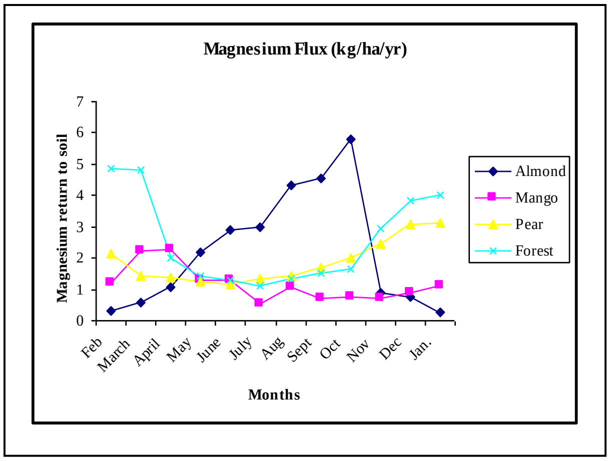


Fig 5.7: Seasonal Variations in Magnesium Flux

The seasonal pattern of calcium returns to the soil through litterfall as shown in fig. 5.5 indicates that Indian almond tree stands returned the highest amount of potassium to the soil than the other isolated tree stands and the adjoining rainforest, in the process of nutrient cycling. As could be observed, the highest amounts of calcium returned to the soil by the stands of Indian almond, mango, avocado pear and the adjoining rainforest are recorded in the months of October, March, January and February respectively. The seasonal pattern of calcium return therefore shows that apart from the Indian almond tree stands, the returns of calcium by the stands of mango, avocado pear and the adjoining rainforest are associated with the dry season months.

Also, the seasonal pattern of sodium returns to the soil through litterfall, as presented in fig 5.6 shows that, Indian almond tree stands returned the highest amount of sodium to the soil during the rainy season, while the stands of mango, avocado pear and the adjoining rainforest returned more sodium to the soil during the dry season. Fig 5.7 shows the seasonal pattern of magnesium return to the soil through litterfall. As observed from the returns of other nutrient elements, Indian almond tree stands returned the highest amount of magnesium to the soil in the process of nutrient cycling. The peak of magnesium return to the soil from the stands of Indian almond, mango, avocado pear and the adjoining rainforest were observed in the months of October, April, January and February respectively. The seasonal pattern of magnesium returns to the soil is similar to that of potassium returns and therefore, shows that the stands of Indian almond and mango trees returned more potassium to the soil during the rainy season than in the dry season, while the avocado pear stands and adjoining rainforest returned more potassium during the dry season.

5.2.7 Interrelationships between Litter Production and Nutrient Returns through Litterfall.

The Pearson's bivariate correlation analysis was employed to examine the interrelationships between litter production and the returns of nutrient elements to the soils through litterfall in each of the isolated tree stands and the adjoining rainforest respectively.

The results presented in table 5.7 show that the relationships between litter production and the nutrient elements returned to the soil through litterfall are all significant and positively correlated for the isolated tree stands and the adjoining rainforest respectively.

Table 5.7: Pearson's bivariate correlations between litter production and nutrient returns in litterfall.

Sites	Litter production	Nutrient elements					
		Nitrogen	Phosphorus	Potassium	Calcium	Sodium	Magnesium
Indian almond	Litter	0.995**	0.986**	0.999**	0.988**	0.984**	0.987**
	Sig. (2-tailed)	0.001	0.001	0.001	0.001	0.001	0.001
	N	12	12	12	12	12	12
Mango	Litter	0.827**	0 .735*	0 .964**	0.692*	0 .986**	0 .978**
	Sig. (2-tailed)	0 .001	0.031	0.001	0.043	0.002	0 .001
	N	12	12	12	12	12	12
Avocado pear	Litter	0.782*	0.848**	0.760**	0.911**	0.854**	0.906**
	Sig. (2-tailed)	0 .024	0.001	0.004	0.001	0.001	0.001
	N	12	12	12	12	12	12
Rainforest	Litter	0.972**	0.991**	0.944**	0.972**	0.949**	0.987**
	Sig. (2-tailed)	0.001	0.001	0.001	0.001	0.001	0.001
	N	12	12	12	12	12	12

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

* Correlation is significant at the 0.05 level (2-tailed)

5.3 Volume of Throughfall, Stemflow and Incident Rainfall

Throughfall volumes vary amongst the isolated tree stands and the adjoining rainforest. The total measured annual volume of throughfall for the Indian almond, mango, avocado pear and the adjoining rainforest are 3857.90 mm, 3831.95 mm, 3935.75 mm and 3641.65 mm respectively (appendix 5.99). These values accounted for 89.2%, 88.6%, 91.0%, and 84.2 % of the measured incident rainfall volume of 4325 mm. These values fall within the range of throughfall values reported for tropical rainforests in the Amazon basin with 78-91% (Lloyd and Marques, 1988; Elsenbeer *et al*., 1994; Filoso *et al*., 1999; Tobon Marin *et al*., 2000); tropical rainforests of south western Amazonia with 89.9% by Germer *et al*. (2006); tropical rainforest of Cameroun with 92.4 – 96.6% by Chunyong *et al.* (2004); and in Nigerian rainforest with 78.8% by Muoghalu and Oakhumen (2000). The throughfall volume varied with the seasons of the year, but did not differ significantly at the 5% level of confidence amongst the isolated tree stands and the adjoining rainforest (appendix 5.99).

The total measured annual volume of stemflow for the Indian almond, mango, avocado pear and the adjoining rainforest are 281.1 mm, 268.2 mm, 328.7 mm and 315.7 mm respectively (appendix 5.100). These values accounted for 6.5%, 6.2%, 7.6% and 7.3 % respectively of the measured incident rainfall volume of 4325 mm, and they fall close to stemflow values reported for tropical rainforest in Nigeria with 5.2% (Muoghalu and Oakhumen, 2000). However, the values differ from results reported in studies by Chuyong *et al*., (2004) with stemflow values of 1.5 - 2.2% in the rainforest of Cameroun. Like the throughfall volume, the stemflow volume varies with the seasons of the year, but did not differ significantly at the 5% confidence levels amongst the isolated tree stands and the adjoining rainforest (appendix 5.100).

5.4 Nutrient Concentrations and Returns to Soil via Throughfall

Nutrient cycles in rainforest ecosystem are closely linked to the hydrological cycle because water acts as the main solvent and transporting agent for nutrient elements from the aboveground tree stands to the soil underneath (Bruijnzeel, 1989). However, throughfall has been observed to be an important source of nutrients return to the soil underneath tree stands (Parker, 1983; Chuyong *et al.*, 2004). The concentrations and returns of nutrient elements via throughfall vary amongst the isolated tree stands and the adjoining rainforest, as well as the seasons of the year. However, the amount of nutrient elements in incident rainfall is generally lower than those in throughfall from the isolated tree stands and the adjoining rainforest. Although, throughfall is observed to be generally a relatively minor vector for the transfer of sodium, nitrogen, phosphorus and calcium to the soil, it was observed to be a major pathway for the transfer of potassium to the soil.

5.4.1 Nutrient Concentrations in Throughfall

The concentrations of nutrient elements in throughfall vary amongst the isolated tree stands and the adjoining rainforests. This is in line with the observations in studies by Muoghalu and Oakhumen (2000) in the Nigerian rainforest, where the concentrations of nutrient elements were reported to be affected by tree species.

Table 5.8 shows the mean annual concentrations of nutrient elements in throughfall, while appendices 5.24 – 5.29 present the monthly concentrations of the nutrient elements from the isolated tree stands, incident rainfall and the adjoining rainforest. The concentrations of nutrient elements are higher in throughfall than in the incident rainfall. Studies by Madgwick and Ovington (1959), Carlisle *et al.* (1966) have observed that throughfall has higher concentrations of dissolved nutrients than the incident rainfall. Although some of this enrichment is due to the leaching of nutrients out of the plant tissue, part is due to the capture of airborne particles (aerosols) by the tree stands. While the concentrations of N, K and Ca are higher in the adjoining rainforest, the concentrations of P, Na and Mg are higher in the isolated tree stands. The observed higher concentration of potassium in throughfall is in line with findings in studies by Muoghalu and Oakhumen (2000), and corroborates the report of studies by Vitousek and Sanford (1986) that, throughfall is a major pathway for the return of potassium to the rainforest soil.

Table 5.8: Mean concentrations of nutrient elements in throughfall in mg l^{-1} yr^{-1}

Nutrient elements	Sites				
	Indian almond *(Terminalia cattapa*	Mango *(Mangifera indica)*	Avocado pear *(Persea gratissima)*	Adjoining rainforest	Incident Rainfall
Nitrogen	5.99	5.63	5.35	6.64	0.20
Phosphorus	5.06	5.42	4.39	4.41	0.16
Potassium	62.51	52.77	40.15	65.39	2.43
Calcium	30.58	27.83	23.88	31.27	2.09
Sodium	0.89	0.98	0.99	0.90	0.08
Magnesium	21.45	21.29	21.87	19.63	2.16

The concentration of nutrient elements in the adjoining rainforest and the incident rainfall, as well as the higher concentrations of Ca and K corroborates findings in the studies by Chuyong *et al.,* (2004) in the rainforest of Cameroun, but higher than findings in the studies by Schrumpf *et al.,* (2006) in the montane rainforest of Tanzania. The concentration of nutrient elements in throughfall is higher during the dry season.

5.4.2 TESTING OF HYPOTHESIS

H1: The concentrations and returns of nutrient elements to the soil through litterfall and rainwash vary amongst the isolated tree stands and the adjoining rainforest.

In order to test the hypothesis, the one-way analysis of variance statistics was employed to examine the differences in the concentrations of nutrient elements in throughfall amongst the isolated tree stands, incident rainfall and the adjoining rainforest respectively. The results of the analyses are as presented in table 5.9. The results revealed that the concentrations of N, P, K, Ca, Na and Mg are significantly different at the 5% confidence levels. Therefore, the stated hypothesis is accepted.

Multiple comparisons of the differences in the mean concentrations of the nutrient elements using the LSD test (appendices 5.31 – 5.36) revealed the pairs of means where the significant differences are observed. Mean differences in the concentrations of nitrogen in throughfall were observed between the pairs of Indian almond and incident rainfall, mango and incident rainfall, avocado pear and the adjoining rainforest, avocado pear and incident rainfall, as well as between the adjoining rainforest and incident rainfall respectively. Apart from the observed difference in the mean values between avocado pear and adjoining rainforest, the concentrations of nitrogen were similar amongst the isolated tree stands and the adjoining rainforest.

Table 5.9: Results of one-way analysis of variance for nutrient concentrations in throughfall amongst avocado pear, mango, Indian almond, incident rainfall and adjoining rainforest

Nutrient Element	Groups	Sum of squares	d/f	Mean square	F	Table F	Level of significance
Nitrogen	Between	322.963	4	80.741	51.288	2.61	0.05
	Within	86.584	55	1.574			
	Total	409.547	59				
Phosphorus	Between	218.075	4	54.519	21.891	2.61	0.05
	Within	136.973	55	2.490			
	Total	355.048	59				
Potassium	Between	31410.168	4	7852.542	25.616	2.61	0.05
	Within	16860.462	55	306.554			
	Total	48270.630	59				
Calcium	Between	7043.054	4	1760.764	16.961	2.61	0.05
	Within	5709.848	55	103.815			
	Total	12752.902	59				
Sodium	Between	7.116	4	1.779	49.966	2.61	0.05
	Within	1.958	55	0.036			
	Total	9.075	59				
Magnesium	Between	3464.674	4	866.169	17.104	2.61	0.05
	Within	2785.302	55	50.642			
	Total	6249.976	59				

*** Significant at F > critical table F (2.61) at the 0.05 level**

The mean differences in the concentrations of phosphorus in throughfall were observed between the pairs of Indian almond and incident rainfall, mango and incident rainfall, avocado pear and incident rainfall, as well as between the adjoining rainforest and incident rainfall respectively. This shows that the concentrations of phosphorus are similar amongst the isolated tree stands and the adjoining rainforest. The mean differences in the concentrations of potassium in throughfall are between the pairs of Indian almond and avocado pear, Indian almond and incident rainfall, mango and incident rainfall, avocado pear and adjoining rainforest, avocado pear and incident rainfall, and between adjoining rainforest and incident rainfall respectively.

The mean differences in the concentrations of calcium in throughfall were observed between the pairs of Indian almond and incident rainfall, mango and incident rainfall, avocado pear and incident rainfall, as well as between the adjoining rainforest and incident rainfall respectively. The concentrations of calcium are similar amongst the isolated tree stands and the adjoining rainforest. The mean differences in the concentrations of sodium in throughfall were observed between the pairs of Indian almond and incident rainfall, mango and incident rainfall, avocado pear and incident rainfall, as well as between the adjoining rainfall and incident rainfall respectively. The mean differences in the concentrations of magnesium in throughfall were observed between the pairs of Indian almond and incident rainfall, mango and incident rainfall, avocado pear and incident rainfall, as well as between the adjoining rainforest and incident rainfall respectively. Generally, the mean concentrations of nutrient elements such as N, P, Ca, Na, and Mg did not vary amongst the isolated tree stands and the adjoining rainforest. This shows that the concentrations of these nutrient elements are on the one hand similar among the isolated tree stands, and on the other hand, they are not different from the observed concentrations in the adjoining rainforest.

5.4.3 pH Values of Throughfall and Incident Rainfall

The monthly pH values in throughfall vary amongst the isolated tree stands, incident rainfall and the adjoining rainforest at the 5% confidence level (appendix 5.37). The mean annual pH values for the Indian almond, mango, avocado pear, adjoining rainforest and incident rainfall are 5.24, 5.61, 5.73, 5.34 and 6.09 respectively. This indicates that pH in the incident rainfall is higher than those of the isolated tree stands and adjoining rainforest. However, among the isolated tree stands and the adjoining rainforest, the mean pH value of throughfall is highest in the stands of avocado pear, and lowest in the stands of Indian almond. Therefore, the concentration of hydrogen ions in throughfall is highest in the stands of Indian almond and lowest in the incident rainfall; though, the acid content is moderate for the isolated tree stands and the adjoining rainforest.

5.4.4 Nutrients Return to the Soil via Throughfall

The returns of nutrient elements to the soil via throughfall vary amongst the isolated tree stands and the adjoining rainforest, as well as the seasons of the year. The seasonal pattern of nutrient return is that of higher nutrient return to the soil during the dry season, especially during the early and late rains. The reason for the higher returns of nutrient elements to the soil during the early rains, has been attributed to the washing off of dry-deposited harmattan dust (Chuyong *et al.,* 2004). In the process of nutrient cycling, the net returns of nutrient elements to the soil via throughfall accounts for the amount of nutrients circled from the tree plants to the soils underneath. The monthly returns of nutrient elements to the soil via throughfall are presented in appendices 5.38 – 5.43.

Table 5.10: Mean annual returns of nutrient elements via throughfall in kg/ha/yr

Nutrient elements	**Sites**			
	Indian almond *(Terminalia cattapa)*	**Mango *(Mangifera indica)***	**Avocado pear *(Persea gratissima)***	**Adjoining rainforest**
Nitrogen	4.86	3.43	2.19	6.04
Phosphorus	0.62	0.78	0.32	0.54
Potassium	10.55	9.47	7.37	8.76
Calcium	6.84	5.77	4.08	4.46
Sodium	0.46	0.81	0.85	0.65
Magnesium	4.16	2.17	4.65	2.13

Table 5.10 shows the mean annual returns of nutrient elements to the soil via throughfall. The returns of the different nutrient elements vary amongst the isolated tree stands and the adjoining rainforest. While the returns of Nitrogen is highest in the adjoining rainforest, P is highest in mango, K and Ca are highest in Indian almond, and Na and Mg are highest in Avocado pear stands respectively. This shows that apart from the returns of nitrogen, nutrient elements returned to the soil are all higher in the isolated tree stands than in the adjoining rainforest. Generally, the returns of Ca, N and K are higher than those of Mg, P and Na. The return of K to the soil is highest. These results corroborate with findings in the study by Muoghalu *et al.* (2000), Levia (2003), and Chuyong *et al.* (2004).

5.4.5 TESTING OF HYPOTHESIS

H1: The concentrations and returns of nutrient elements to the soil through litterfall and rainwash vary amongst the isolated tree stands and the adjoining rainforest.

In order to test the hypothesis, the one-way analysis of variance statistics was employed to examine the differences in the returns of nutrient elements to the soil via throughfall amongst the isolated tree stands and the adjoining rainforest respectively. The results of the analyses are as presented in table 5.11. The results revealed that apart from Sodium returns, the returns of nutrient elements to the soil via throughfall are significantly different at the 5% confidence level. Therefore, the stated hypothesis is accepted.

Multiple comparisons of the differences in the mean returns of the nutrient elements using the LSD test (appendices 5.44 – 5.49) present the pairs of the means where the observed mean differences in the returns of N, P, K, Ca and Mg are.

Table 5.11: Results of one-way analysis of variance for nutrient returns via throughfall amongst avocado pear, mango, Indian almond and adjoining rainforest

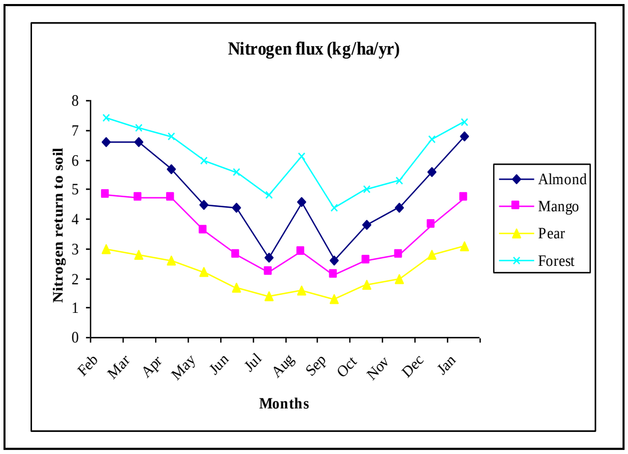
Nutrient Element	**Groups**	**Sum of squares**	**d/f**	**Mean square**	**F**	**Sig.**
Nitrogen	Between	100.447	3	33.482	29.052	0.001
	Within	50.710	44	1.153		
	Total	151.157	47			
Phosphorus	Between	1.402	3	0.467	5.050	0.004
	Within	4.073	44	0.093		
	Total	5.475	47			
Potassium	Between	64.097	3	21.366	2.886	0.046
	Within	325.793	44	7.404		
	Total	389.890	47			
Calcium	Between	57.467	3	19.156	2.673	0.054
	Within	315.265	44	7.165		
	Total	372.732	47			
Sodium	Between	1.133	3	0.378	2.441	0.077
	Within	6.805	44	0.155		
	Total	7.937	47			
Magnesium	Between	62.308	3	20.769	4.745	0.006
	Within	192.578	44	4.377		
	Total	254.886	47			

5.4.6 Seasonal Variations in Returns of Nutrient Elements via Throughfall

The trend in the returns of nutrient elements to the soil via throughfall amongst the isolated tree stands and the adjoining rainforest varies with the seasons of the year (Fig 5.8 – 5.13). The trend in the seasonal returns of nutrient elements to the soil is similar amongst the isolated tree stands and the adjoining rainforest. Nutrient returns to the soil via throughfall are lowest in the rainy season months and highest in the dry season months. The higher nutrient flux in the dry season months could be attributed to the trapped dust particles by the tree stands which are washed down to the soil as throughfall. The dust particles, according to Vitousek and Sanford (1986), contain nutrient elements and serve as source of nutrient return to the soil in nutrient cycling. The returns of nutrient elements are higher in the month of August than the observed returns in the months of July and September, and could possibly be as a result of the dry dusty wind associated with the August break.

From fig 5.8, Indian almond, Mango, avocado pear and the adjoining rainforest returned the highest nitrogen in January, February, January and February respectively, while the corresponding lowest returns of nitrogen are in the month of September respectively. From fig 9, Indian almond and Mango returned the highest phosphorus in February while avocado pear and the adjoining rainforest returned the highest phosphorus in January respectively. The highest amount of phosphorus returned to the soil is by mango tree stands while the lowest amount of phosphorus returned to the soil is by avocado pear stands.

Fig 5.10 shows the seasonal pattern of potassium return to the soil via throughfall. Indian almond tree stands returned the highest amount of potassium (14.3 kg/ha/yr) to the soil in the process of nutrient cycling, although the returns of K is highest for all the nutrient elements returned amongst the isolated tree stands and the adjoining rainforest. As could be observed, Indian almond and the adjoining rainforest returned the highest potassium to the soil in January, while mango and avocado pear stands returned the highest potassium to the soil in February. The corresponding lowest amount of potassium was returned to the soil by Indian almond in July while mango, avocado pear and the adjoining rainforest returned the lowest potassium to the soil in September respectively.



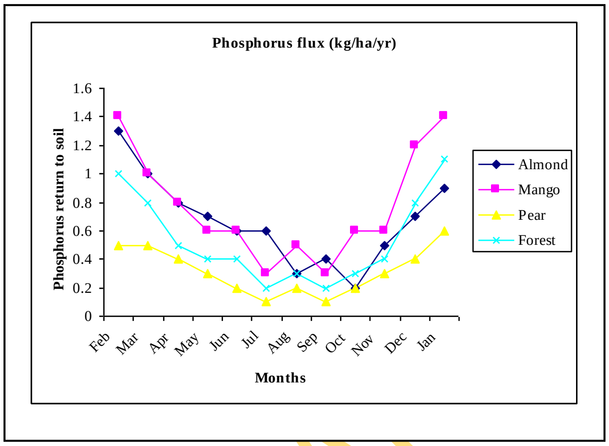
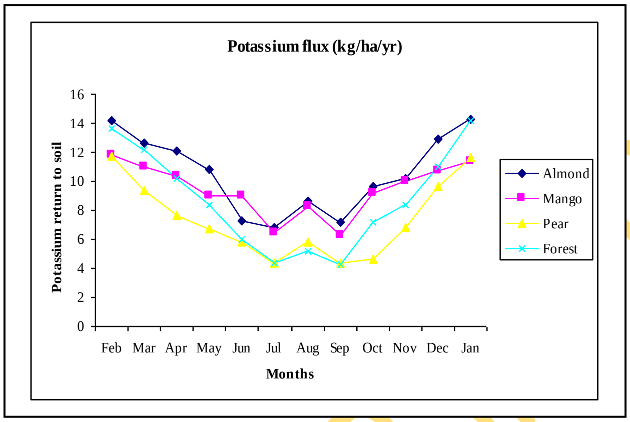


Fig 5.8: Seasonal variations in Nitrogen flux

Fig 5.9: Seasonal variations in Phosphorus flux



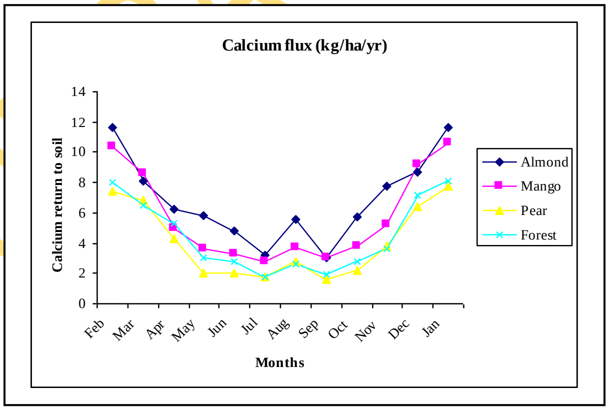
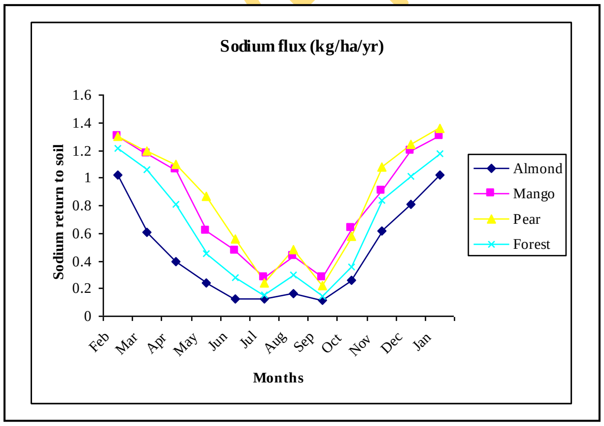


Fig 5.10: Seasonal variations in Potassium flux

Fig 5.11: Seasonal variations in Calcium flux



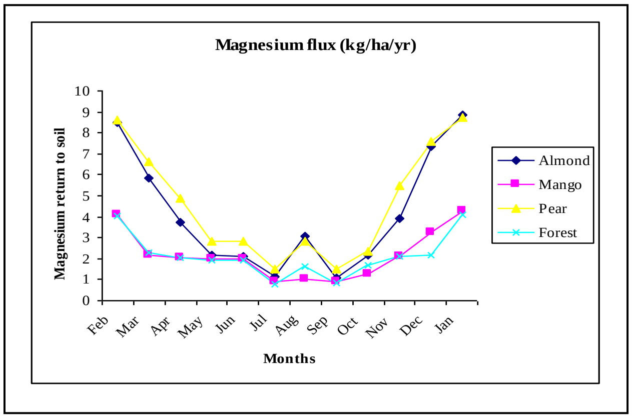


Fig 5.12: Seasonal variations in Sodium flux

Fig 5.13: Seasonal variations in Magnesium flux

The seasonal pattern of potassium return therefore shows that both the isolated tree stands and the adjoining rainforest return more potassium to the soil via throughfall during the dry season.

The seasonal pattern of calcium returns to the soil via throughfall as shown in fig.5.11indicates that Indian almond tree stands returned the highest amount of potassium to the soil than the other isolated tree stands and the adjoining rainforest. The highest amounts of calcium returned to the soil by the stands of Indian almond, mango, avocado pear and the adjoining rainforest were observed in January, while the lowest amount of calcium returned to the soil was observed in September, July, September and July respectively. The seasonal pattern therefore shows that higher amount of calcium is returned to the soil in the dry season than in the rainy season.

Also, the seasonal pattern of sodium returns to the soil via throughfall, as presented in fig 5.12 shows that, although the amount is generally low, sodium returns to the soil is higher in the rainy season than in the dry season. The highest return of sodium to the soil was observed in avocado pear stands, and it is associated with the dry season months; while the lowest returns of sodium was observed in the rainy season months.

However, fig 5.13 shows the seasonal pattern of magnesium returns to the soil via throughfall. As observed from the returns of other nutrient elements, higher returns of magnesium was observed in the dry season months especially within January and February, while the lowest returns was observed in the rainy season months, between July and September. From fig 5.8 – 5.13, it could therefore be deduced that the returns of nutrient elements to the soil via throughfall is higher in the dry season and lower in the rainy season respectively.

5.5 NUTRIENT CONCENTRATIONS AND RETURNS TO SOIL VIA STEMFLOW

Stemflow, like throughfall, also return nutrient elements to the soil. Although the amount of nutrient elements returned to the soil is lower than that of throughfall. Nutrients from stemflow are generally a small fraction of those in throughfall, which obviously falls in line with the study by Parker (1983) where stemflow was observed to be generally less than 10% of those in throughfall in mature forests.

The concentrations and returns of nutrient elements through stemflow vary amongst the isolated tree stands and the adjoining rainforest, as well as the seasons of the year. The concentrations of nutrient elements in incident rainfall shows that rain water contains nutrient elements and thus contributes to nutrients return to the soil. However, the amount of nutrient elements in incident rainfall is generally lower than those in stemflow from the isolated three stands and the adjoining rainforest respectively. This shows that stemflow has higher concentrations of dissolved nutrients than the incident rainfall. While some of this enrichment is due to the leaching of materials out of the plant tissue, part is due to the capture of airborne particles (aerosols) by the tree stands. According to Madgwick and Ovington (1959), Carlisle *et al.*, (1966), the aerosol components arise from smoke, reactions between gases in the atmosphere, sea spray and mineral dust.

5.5.1 Nutrient Concentrations in Stemflow

The concentrations of nutrient elements in stemflow vary amongst the isolated tree stands and the adjoining rainforest. The concentration of nutrient elements is higher in the rainy season than in the dry season for both the isolated tree stands and the adjoining rainforest (appendices 5.50 – 5.55). From table 5.12, the mean concentrations of nutrient elements in stemflow are generally lower in the incident rainfall than in the isolated tree stands and the adjoining rainforest.

While the concentration of N and Na is highest in the adjoining rainforest, the concentration of P is highest in the stands of mango trees, and that of K, Ca and Mg is highest in the stands of Indian almond trees. Generally, the concentrations of K, Ca and Mg are higher in the stemflow for the isolated tree stands and the adjoining rainforest respectively. The observed higher concentration of potassium in stemflow is in line with findings in studies by Muoghalu and Oakhumen (2000) in a Nigerian rainforest where the concentration of K is highest in all the nutrient elements investigated.

Table 5.12: Mean concentrations of nutrient elements in stemflow in mg l^{-1}

Nutrient elements	**Sites**				
	Indian almond *(Terminalia cattapa)*	**Mango *(Mangifera indica)***	**Avocado pear *(Persea gratissima)***	**Adjoining rainforest**	**Incident Rainfall**
Nitrogen	0.65	0.44	0.55	0.71	0.20
Phosphorus	0.54	0.63	0.39	0.54	0.16
Potassium	12.33	10.36	11.31	12.12	2.43
Calcium	6.22	5.42	6.18	5.80	2.09
Sodium	0.41	0.39	0.42	0.43	0.08
Magnesium	4.78	3.90	4.40	4.69	2.16

5.5.2 TESTING OF HYPOTHESIS

H1: The concentrations and returns of nutrient elements to the soil through litterfall and rainwash vary amongst the isolated tree stands and the adjoining rainforest.

In order to test the hypothesis, the one-way analysis of variance statistics was employed to examine the differences in the concentrations of nutrient elements in stemflow amongst the isolated tree stands and the adjoining rainforest respectively. The results of the analyses are as presented in table 5.13. The results revealed that there are significant differences in the concentrations of nutrient elements in stemflow amongst the isolated tree stands and the adjoining rainforest at the 5% confidence level. Therefore, the stated hypothesis is accepted.

However, multiple comparisons of the mean differences using the LSD test (appendices 5.57 – 5.62) revealed the pairs of means where the significant differences are. From table 5.13, the concentrations of all the nutrient elements are significantly different in stemflow for all the sample sites at the 5% confidence levels.

Table 5.13: Results of one-way analysis of variance for nutrient concentrations in stemflow amongst avocado pear, mango, Indian almond, adjoining rainforest and incident rainfall.

Nutrient Element	Groups	Sum of squares	d/f	Mean square	F	Table F	Level of significance
Nitrogen	Between	1.899	4	0.475	41.804	2.61	0.05
	Within	0.625	55	0.011			
	Total	2.524	59				
Phosphorus	Between	1.693	4	0.423	41.165	2.61	0.05
	Within	0.566	55	0.010			
	Total	2.259	59				
Potassium	Between	823.186	4	205.796	135.120	2.61	0.05
	Within	83.768	55	1.523			
	Total	906.954	59				
Calcium	Between	144.419	4	36.105	42.829	2.61	0.05
	Within	46.365	55	0.843			
	Total	190.784	59				
Sodium	Between	1.063	4	0.266	38.161	2.61	0.05
	Within	0.383	55	0.007			
	Total	1.446	59				
Magnesium	Between	55.676	4	13.919	91.563	2.61	0.05
	Within	8.361	55	0.152			
	Total	64.037	59				

*** Significant at F > critical table F (2.61) at the 0.05 level**

5.5.3 pH Values in Stemflow and Incident Rainfall

The monthly pH values in stemflow vary amongst the isolated tree stands, incident rainfall and the adjoining rainforest at the 5% confidence level (appendix 5.56). The mean annual pH values for the Indian almond, mango, avocado pear, adjoining rainforest and incident rainfall are 5.7, 5.7, 5.1, 5.3 and 6.0 respectively. This indicates that pH in the incident rainfall is higher than those of the isolated tree stands and adjoining rainforest. However, among the isolated tree stands and the adjoining rainforest, the mean pH value of stemflow is highest in the stands of Indian almond and mango, and lowest in the stands of avocado pears. Therefore, the concentration of acid in throughfall is highest in the stands of avocado pear and lowest in the incident rainfall; although, the acid content is moderate for the isolated tree stands and the adjoining rainforest.

5.5.4 Returns of Nutrient Elements to the Soil via Stemflow

The returns of nutrient elements to the soil via stemflow vary amongst the isolated tree stands and the adjoining rainforest, as well as the seasons of the year. The seasonal pattern of nutrient returns is that of higher nutrient return to the soil in the rainy season than in the dry season. In the process of nutrient cycling, the net returns of nutrient elements through stemflow accounts for the amount of nutrients circled from the tree stands to the soils underneath. The monthly returns of nutrient elements to the soil via stemflow are presented in appendices 5.64 – 5.69, while the mean annual returns of nutrient elements are presented in table 5.14 respectively.

From table 5.14, the mean annual returns of the different nutrient elements vary amongst the isolated tree stands and the adjoining rainforest. While the returns of N, P and Na are highest in the adjoining rainforest, K, Ca and Mg are highest in Indian almond tree stands respectively. This shows that amongst the isolated tree stands, the returns of nutrient elements such as N, P, K, Ca and Mg are all higher in the stands of Indian almond except for the returns of Na which was observed to be highest in the stands of avocado pear.

Table 5.14: Mean annual returns of nutrient elements via Stemflow in kg/ha

Nutrient elements	Sites			
	Indian almond *(Terminalia cattapa)*	Mango *(Mangifera indica)*	Avocado pear *(Persea gratissima)*	Adjoining rainforest
Nitrogen	0.39	0.25	0.17	0.47
Phosphorus	0.05	0.04	0.03	0.08
Potassium	0.69	0.32	0.36	0.67
Calcium	0.68	0.42	0.62	0.28
Sodium	0.07	0.04	0.11	0.14
Magnesium	0.83	0.26	0.60	0.55

5.5.5 TESTING OF HYPOTHESIS

H1: The concentrations and returns of nutrient elements to the soil through litterfall and rainwash vary amongst the isolated tree stands and the adjoining rainforest.

In order to test the hypothesis, the one-way analysis of variance statistics was employed to examine the differences in the returns of nutrient elements to the soil via stemflow amongst the isolated tree stands and the adjoining rainforest respectively. The results of the analyses are as presented in table 5.15. The results revealed that the returns of nutrient elements to the soil via stemflow are significantly different amongst the isolated tree stands and the adjoining rainforest at the 5% confidence levels. Therefore, the stated hypothesis is accepted.

However, multiple comparisons of the differences in the mean returns of the nutrient elements using the LSD test (appendices 5.70 – 5.75) revealed the pairs of mean where the significant differences are respectively.

Table 5.15: Results of one-way analysis of variance for nutrient returns via stemflow amongst avocado pear, mango, Indian almond and adjoining rainforest

Nutrient Element	Groups	Sum of squares	d/f	Mean square	F	Sig.
Nitrogen	Between	0.656	3	0.219	5.689	0.002
	Within	1.691	44	0.038		
	Total	2.347	47			
Phosphorus	Between	0.016	3	0.005	4.111	0.012
	Within	0.058	44	0.001		
	Total	0.074	47			
Potassium	Between	1.415	3	0.472	4.100	0.012
	Within	5.062	44	0.115		
	Total	6.477	47			
Calcium	Between	1.238	3	0.413	3.894	0.015
	Within	4.664	44	0.106		
	Total	5.902	47			
Sodium	Between	0.062	3	0.021	5.772	0.002
	Within	0.159	44	0.004		
	Total	0.221	47			
Magnesium	Between	1.989	3	0.663	4.115	0.012
	Within	7.088	44	0.161		
	Total	9.077	47			

5.5.6 Seasonal Variations in Returns of Nutrient Elements to the Soil via Stemflow

The returns of nutrient elements to the soil via stemflow amongst the isolated tree stands and the adjoining rainforest vary with the seasons of the year (Fig 5.14 – 5.19). The trend in the seasonal returns of nutrient elements to the soil is similar amongst the isolated tree stands and the adjoining rainforest because the returns of nutrient elements are all lower in the dry season and higher in the rainy season, with observed reduction in the month of August. The higher nutrient flux during the peak of the rainy season could be accounted for by the ability of the heavy and constant rainfall to soak the tree trunk and barks, and therefore wash down more nutrient elements during this period. During the dry season, the reduced amount and frequency of rainfall affects the washing down of nutrient elements to the soil via stemflow (Vitousek and Sanford (1986)).

From fig 5.14, Indian almond, Mango, avocado pear and the adjoining rainforest returned the highest nitrogen in September, September, July and September respectively, while the corresponding lowest returns of nitrogen are generally observed in January and February. While Indian almond and avocado pear returned the highest phosphorus in July, the adjoining rainforest returned the highest phosphorus in September, and the highest returned of phosphorus in the stands of mango was observed in July and September (Fig 5.15). However, the lowest amount of phosphorus returned to the soil was found to be between the months of January and February. Fig 5.16 shows the seasonal pattern of potassium return to the soil via stemflow. Indian almond tree stands and the adjoining rainforest returned the highest amount of potassium (1.4 kg/ha) to the soil in September, while mango and avocado pear stands returned the highest potassium (0.8 kg/ha) in the month of July respectively. The corresponding lowest amount of potassium was returned to the soil within January and February respectively. This shows that the seasonal trend in the returns of potassium is highest in the rainy season and lowest in the dry season months respectively. The seasonal pattern of calcium returns to the soil via stemflow as shown in fig.5.17 indicates that while the highest returns of calcium by the stands of Indian almond, mango and the adjoining rainforest is in September, the returns of calcium to the soil by the stands of avocado pear is in July. This also shows that the returns of calcium to the soil are highest in the rainy season and lowest in the dry season.

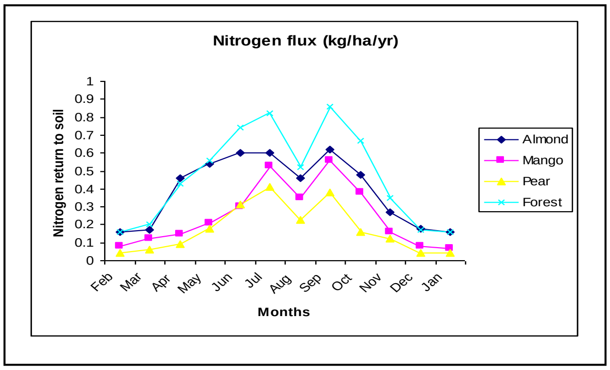


Fig 5.14: Seasonal variations in Nitrogen flux

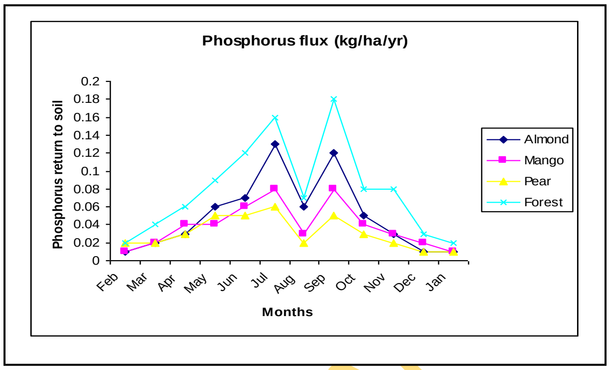


Fig 5.15: Seasonal variations in Phosphorus flux

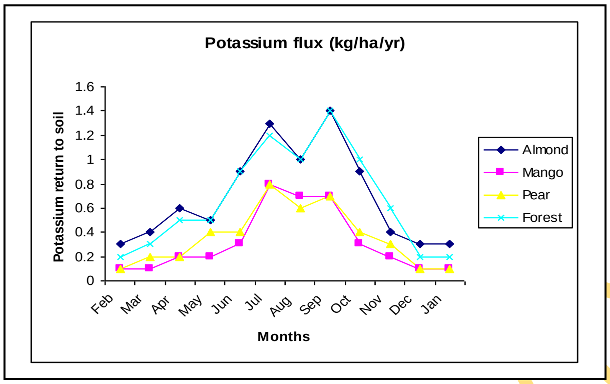


Fig 5.16: Seasonal variations in Potassium flux

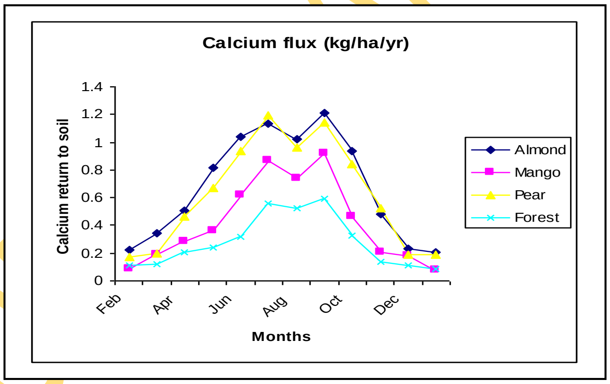


Fig 5.17: Seasonal variations in Calcium flux

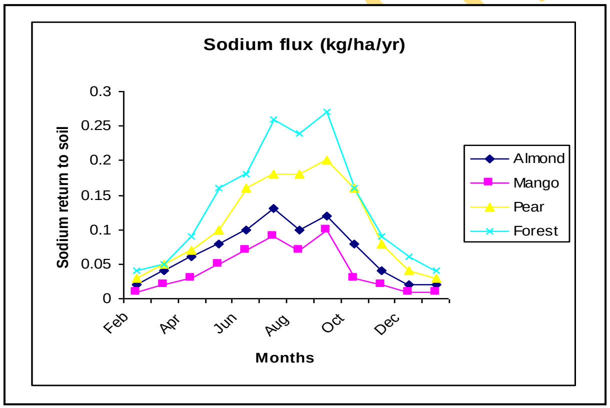


Fig 5.18: Seasonal variations in Sodium flux

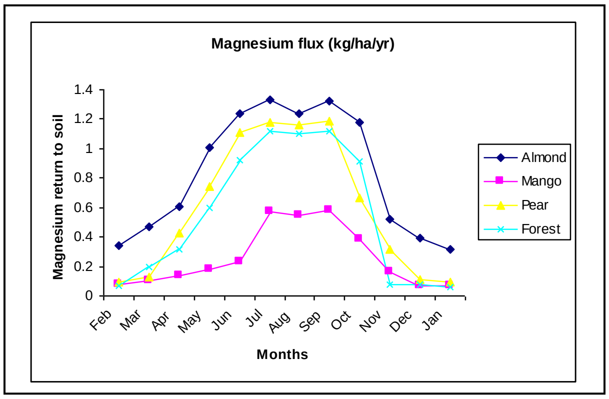


Fig 5.19: Seasonal variations in Magnesium flux

The seasonal pattern therefore shows that higher amount of calcium is returned to the soil through stemflow in the rainy season than in the dry season.

Also, the seasonal pattern of sodium returns to the soil via stemflow, as presented in fig 5.18 shows that, although the amount is generally low, sodium returns to the soil is higher in the rainy season than in the dry season.

The highest returns of sodium (1.33 kg/ha) to the soil was observed in the stands of Indian almond, and it is associated with the rainy season months. Conversely, the lowest returns of sodium (0.06 kg/ha) which was observed in the adjoining rainforest, was recorded in the dry season month (January). Fig 5.19 shows the seasonal pattern of magnesium returns to the soil via stemflow. Just like the observed trend in the returns of other nutrient elements to the soil by the isolated tree stands and the adjoining rainforest, the returns of magnesium to the soil are generally highest in the rainy season (between July and September), while the lowest returns of magnesium was observed in the dry season months (January and February) respectively.

It could therefore be deduced that the returns of nutrient elements to the soil via stemflow is higher in the rainy season months and lower in the dry season months respectively.

5.6 Differences in the Returns of Nutrient Elements to the Soil via Litterfall, Throughfall and Stemflow

The returns of nutrient elements to the soil via litterfall, throughfall and stemflow vary significantly. From table 5.16, litterfall returned the highest amount of N, P and Ca kg/ha/yr; while throughfall returned the highest amount of K, Na and Mg kg/ha/yr respectively. It has earlier been stated that though stemflow returns nutrient elements to the soil, the amount of nutrients returned to the soil is relatively small. In comparing the returns of nutrient elements via litterfall and rainwash, it was observed that stemflow returned the least amount of nutrients to the soil under the isolated tree stands and the adjoining rainforest.

Table 5.16: Mean annual returns of nutrient elements via litterfall, throughfall and stemflow in kg/ha

Nutrient elements	**Sources of nutrients**	**Sites**			
		Indian almond *(Terminalia cattapa)*	**Mango *(Mangifera indica)***	**Avocado pear *(Persea gratissima)***	**Adjoining rainforest**
Nitrogen	Litterfall	5.73	3.43	2.42	9.08
	Throughfall	4.86	2.43	2.19	6.04
	Stemflow	0.39	0.25	0.17	0.47
Phosphorus	Litterfall	0.65	0.45	0.42	0.60
	Throughfall	0.62	0.78	0.32	0.54
	Stemflow	0.05	0.04	0.03	0.08
Potassium	Litterfall	4.92	2.64	2.14	3.39
	Throughfall	10.55	9.47	7.37	8.76
	Stemflow	0.69	0.32	0.36	0.67
Calcium	Litterfall	7.50	5.22	5.37	7.81
	Throughfall	6.84	4.77	4.08	4.46
	Stemflow	0.68	0.42	0.62	0.28
Sodium	Litterfall	0.41	0.25	0.31	0.49
	Throughfall	0.46	0.81	0.85	0.65
	Stemflow	0.07	0.04	0.11	0.14
Magnesium	Litterfall	2.22	1.17	1.87	2.57
	Throughfall	4.16	2.17	4.65	2.13
	Stemflow	0.83	0.26	0.60	0.55

5.6.1 TESTING OF HYPOTHESIS

H1: There is a significant difference in the returns of nutrient elements to the soil through litterfall, throughfall and stemflow.

In order to test the hypothesis, the one-way analysis of variance statistics was employed to examine the differences in the returns of nutrient elements to the soil via litterfall, throughfall and stemflow respectively. The results of the analyses are as presented in tables 5.17 – 5.20. The results revealed that the returns of nutrient elements to the soil via litterfall, throughfall and stemflow are significantly different at the 5% confidence levels. Therefore, the stated hypothesis is accepted.

From table 5.17, it could therefore be deduced that litterfall, throughfall and stemflow do not return the same amount of nutrient elements to the soil under the isolated stands of Indian almond and the adjoining rainforest. However, multiple comparisons of the mean differences using the LSD test revealed the pairs of the means where the mean differences are (appendices5.76 – 5.98).

Table 5.17 presents the results of one-way analysis of variance statistics for the returns of nutrient elements via litterfall, throughfall and stemflow for the stands of Indian almond. There are significant differences in the returns of the nutrient elements through litterfall, throughfall and stemflow at the 5% confidence level.

Table 5.17: Results of one-way analysis of variance for the differences in nutrient returns via litterfall, throughfall and stemflow in the stands of Indian almond

Sources of Nutrients	Nutrient Element	Groups	Sum of squares	d/f	Mean square	F	Sig.
Litterfall	Nitrogen	Between	196.669	2	98.335	10.890	0.001
Throughfall		Within	297.982	33	9.030		
Stemflow		Total	494.651	35			
Litterfall	Phosphorus	Between	2.951	2	1.475	10.342	0.001
Throughfall		Within	4.707	33	0.143		
Stemflow		Total	7.658	35			
Litterfall	Potassium	Between	587.050	2	293.525	33.163	0.001
Throughfall		Within	292.085	33	8.851		
Stemflow		Total	879.135	35			
Litterfall	Calcium	Between	339.635	2	169.817	9.785	0.001
Throughfall		Within	572.736	33	17.356		
Stemflow		Total	912.371	35			
Litterfall	Sodium	Between	1.092	2	0.546	6.583	0.004
Throughfall		Within	2.736	33	0.083		
Stemflow		Total	3.828	35			
Litterfall	Magnesium	Between	67.100	2	33.550	8.694	0.001
Throughfall		Within	127.341	33	3.859		
Stemflow		Total	194.440	35			

Table 5.18: Results of one-way analysis of variance for the differences in nutrient returns via litterfall, throughfall and stemflow in mango stands

Sources of Nutrients	Nutrient Element	Groups	Sum of squares	d/f	Mean square	F	Sig.
Litterfall	Nitrogen	Between	83.291	2	41.646	43.987	0.001
Throughfall		Within	31.243	33	0.947		
Stemflow		Total	114.534	35			
Litterfall	Phosphorus	Between	3.269	2	1.634	27.601	0.001
Throughfall		Within	1.954	33	0.059		
Stemflow		Total	5.223	35			
Litterfall	Potassium	Between	542.835	2	271.418	214.744	0.001
Throughfall		Within	41.709	33	1.264		
Stemflow		Total	584.544	35			
Litterfall	Calcium	Between	207.945	2	103.973	27.640	0.001
Throughfall		Within	124.133	33	3.762		
Stemflow		Total	332.078	35			
Litterfall	Sodium	Between	3.750	2	1.875	34.657	0.001
Throughfall		Within	1.786	33	0.054		
Stemflow		Total	5.536	35			
Litterfall	Magnesium	Between	21.981	2	10.991	19.515	0.001
Throughfall		Within	18.585	33	0.563		
Stemflow		Total	40.566	35			

From table 5.18, the results of one-way analysis of variance show that the returns of nutrient elements to the soil via litterfall, throughfall and stemflow in the stands of mango trees are significantly different at the 5% confidence level. The F-values for the N, P, K, Ca, Na and Mg are 43.987, 27.601, 214.744, 27.640, 34.657 and 19.515 respectively. With significant values of 0.000, it shows that the returns of nutrient elements from the isolated stands of mango trees vary amongst litterfall, throughfall and stemflow.

From table 5.19, the results of one-way analysis of variance show that the returns of nutrient elements to the soil via litterfall, throughfall and stemflow in the stands of Avocado pear trees are significantly different at the 5% confidence level. The F-values for the N, P, K, Ca, Na and Mg are 82.152, 23.992, 51.082, 22.422, 26.123 and 19.300 respectively. With significant values of 0.001, it shows that the returns of nutrient elements from the isolated stands of Avocado pears tree vary amongst litterfall, throughfall and stemflow.

From table 5.20, the results of one-way analysis of variance show that the returns of nutrient elements to the soil via litterfall, throughfall and stemflow in the adjoining rainforest are significantly different at the 5% confidence level. The F-values for the N, P, K, Ca, Na and Mg are 18.351, 11.285, 30.555, 18.023, 8.897 and 12.163 respectively. With significant values of 0.001, it shows that the returns of nutrient elements from the adjoining rainforest vary amongst litterfall, throughfall and stemflow. As earlier indicated, the return of nutrient elements to the soil is highest through litterfall than throughfall and stemflow.

Table 5.19: Results of one-way analysis of variance for the differences in nutrient returns via litterfall, throughfall and stemflow in the stands of avocado pear

Sources of Nutrients	Nutrient Element	Groups	Sum of squares	d/f	Mean square	F	Sig.
Litterfall	Nitrogen	Between	36.668	2	18.334	82.152	0.001
Throughfall		Within	7.365	33	0.223		
Stemflow		Total	44.032	35			
Litterfall	Phosphorus	Between	0.975	2	0.488	23.992	0.001
Throughfall		Within	0.671	33	0.020		
Stemflow		Total	1.646	35			
Litterfall	Potassium	Between	318.391	2	159.195	51.082	0.001
Throughfall		Within	102.843	33	3.116		
Stemflow		Total	421.233	35			
Litterfall	Calcium	Between	144.462	2	72.231	22.422	0.001
Throughfall		Within	106.309	33	3.221		
Stemflow		Total	250.771	35			
Litterfall	Sodium	Between	3.559	2	1.779	26.123	0.001
Throughfall		Within	2.248	33	0.068		
Stemflow		Total	5.806	35			
Litterfall	Magnesium	Between	102.819	2	51.409	19.300	0.001
Throughfall		Within	87.904	33	2.664		
Stemflow		Total	190.722	35			

Table 5.20: Results of one-way analysis of variance for the differences in nutrient returns via litterfall, throughfall and stemflow in the adjoining rainforest

Sources of Nutrients	Nutrient Element	Groups	Sum of squares	d/f	Mean square	F	Sig.
Litterfall	Nitrogen	Between	457.318	2	228.659	18.351	0.001
Throughfall		Within	411.199	33	12.461		
Stemflow		Total	868.517	35			
Litterfall	Phosphorus	Between	1.916	2	0.958	11.285	0.001
Throughfall		Within	2.802	33	0.085		
Stemflow		Total	4.718	35			
Litterfall	Potassium	Between	406.825	2	203.412	30.555	0.001
Throughfall		Within	219.690	33	6.657		
Stemflow		Total	626.515	35			
Litterfall	Calcium	Between	341.567	2	170.783	18.023	0.001
Throughfall		Within	312.707	33	9.476		
Stemflow		Total	654.274	35			
Litterfall	Sodium	Between	1.648	2	0.824	8.897	0.001
Throughfall		Within	3.055	33	0.093		
Stemflow		Total	4.703	35			
Litterfall	Magnesium	Between	27.136	2	13.568	12.163	0.001
Throughfall		Within	36.813	33	1.116		
Stemflow		Total	63.950	35			

5.7 Discussions

Litterfall, throughfall and stemflow have been observed to return nutrient elements to the soil. However, litterfall returns more nutrients to the soil than the throughfall and stemflow (litterfall > throughfall > stemflow). Unlike nutrient returns from litterfall, nutrients input to the soil via throughfall and stemflow are immediately available for plants uptake (Eaton *et al.*,, 1973). Litterfall returned the highest amount of N, P and Ca kg/ha/yr; while throughfall returned the highest amount of K, Na and Mg kg/ha/yr respectively.

Litter production varies amongst the isolated tree stands and the adjoining rainforest, as well as the seasons of the year. Seasonal variation in litter production has been observed in studies by Muoghalu *et al.* (1993), Hermansah *et al.* (2002), Pragasan and Parthasarathy (2005) in the tropical rainforest ecosystems. Litter production in the adjoining rainforest is higher in the dry season months and lower in the rainy season months respectively. The concentrations and returns of nutrient elements in litterfall vary amongst the isolated tree stands and the adjoining rainforest. This variation is probably due to the differences in the tree species because, studies by Proctor (1984), Muoghalu *et al.* (1993), Hermansah *et al.*, (2002), Pragasan and Parthasarathy (2005) have observed that the cycling of nutrient elements vary with variations in tree species composition. The concentrations and returns of all the nutrient elements were highest in the adjoining rainforest except for the concentration of potassium, and the returns of potassium and phosphorus which was higher in Indian almond stands respectively. While calcium concentrations and returns were highest in the isolated tree stands, nitrogen is highest in the adjoining rainforest. The higher flux in these nutrient elements could presumably be due to their high availability in the soil. The order of nutrient concentrations and returns to the soil through litterfall as observed in the isolated tree stands is Ca > N > K > Mg > P > Na while that of the adjoining rainforest is N > Ca > K > Mg > P > Na. The observed order for the isolated tree stands is in line with the observed findings in studies by Leigh *et al.* (1982), Mueller-Dombois *et al.* (1984), and Muoghalu *et al.* (1993); while that of the adjoining rainforest corroborates findings in studies by Bernhard-Reversat (1972 and 1993), and Perez *et al.* (2003). Seasonal variations in the concentrations and returns of nutrient elements to the soil were observed for the isolated tree stands and the adjoining rainforest. While the highest return of nutrients by Indian almond and mango tree stands was observed in the rainy season, avocado pear tree stands returned the highest nutrient elements in the dry season thus, shares a direct similarity in seasonal returns of nutrient elements with the adjoining rainforest. The seasonal pattern of nutrients return in the adjoining rainforest is similar to findings in studies by Muoghalu *et al.* (1993). This shows that in the process of nutrient cycling, the returns of nutrient elements to the soil vary with the seasons of the year. The pH values of litterfall varied amongst the isolated tree stands and adjoining rainforest. However, this study revealed that amongst the isolated tree stands and adjoining rainforest, acid content of litterfall is highest in Indian almond and mango than that of avocado pear stands and the adjoining rainforest respectively.

Throughfall and stemflow have higher concentrations of dissolved nutrients than the incident rainfall. While some of this enrichment is due to the leaching of materials out of the plant tissue (Parker, 1983; Vitousek and Sanford, 1986; Weltzin and Coughenor, 1990; Chuyong *et al.*, 2004), part is due to the capture of airborne particles (aerosols) by the tree plants (Muoghalu and Oakhumen, 2000; Bruijnzeel, 2001). These nutrient elements vary in concentrations and returns to the soil according to the tree species. Nutrients from stemflow are generally a small fraction (about 15%) of those in throughfall. Apart from magnesium return in stemflow which is higher in mango tree stands than in incident rainfall, the highest concentration and returns of each nutrient element to the soil was via throughfall, followed by stemflow and the lowest in incident rainfall. These observations are in line with studies by Muoghalu and Oakhumen (2000) in a Nigerian secondary lowland rainforest, Chuyong *et al.* (2004) in the rainforest ecosystem of Cameroon. The observed variations in the concentrations and returns of nutrient elements amongst the sample sites were all significant, except in the returns of magnesium through stemflow. The returns of nutrient elements vary with seasons of the year, and also between stemflow and throughfall. Nutrient return in stemflow is highest during the heavy-rain months (May and October) while in throughfall, the highest returns of nutrient elements were during the early and late rains. The reason for high nutrients return and the observed seasonal returns of nutrient elements via throughfall is that it is likely due to washing off of dry-deposited harmattan dusts. These further corroborated the observed seasonal variations in nutrients returned to the soil via rainwash as reported by Parker (1983), Muoghalu and Oakhumen (2000), and Chuyong *et al.* (2004). Generally, for both the concentrations and returns of nutrient elements, stemflow and throughfall varied significantly at the 0.05 confidence levels for all the sample sites. Although there were marked variations in the concentrations and returns of nutrient elements through rainwash for the isolated tree stands and the adjoining rainforest, the observed amount of nutrient elements returned to the soil by the isolated tree stands in comparison with the adjoining rainforest shows a close similarity. However, the order of nutrients returned to the soil through stemflow and throughfall is K > Ca > Mg > N > P > Na. This pattern is similar to the observed pattern reported by Chuyong *et al.* (2004). However, it was generally observed that throughfall is the major pathway of potassium return to the soil from the isolated tree stands and the adjoining rainforest.

CHAPTER SIX

SOIL AND PLANT INTERRELATIONSHIPS

6.1 INTRODUCTION

Cycling of matter or nutrients is an important way in which soils and plants exert reciprocal effects on one another. In rainforest ecosystems, plants and soils are closely related and they influence one another. The interrelationship between soil and plants is such that the plants get their nutrients and moisture from the soil in which they grow. As the plants develop, they shed their leaves and branches as litters which decay to enhance the nutrients of the soil that are again absorbed by plants. Dust accumulation on leaves and branches, transported to the soil via throughfall and stemflow is also an important input of nutrient elements to the soil. Nutrients returned to the soil through litterfall, stemflow and throughfall help to maintain soil fertility by increasing the quantities of the nutrient elements in the soil. This chapter therefore presents the interrelationships between plants and soils underneath, by considering plant biomass parameters and soil properties, litter production and soil properties, as well as the relationships between the nutrient content of the soil with the returns of nutrient elements via litterfall, throughfall and stemflow respectively.

6.2 INTERRELATIONSHIPS BETWEEN PLANT BIOMASS PARAMETERS AND SOIL PROPERTIES

Plant biomass parameters are interrelated with the soil physical and nutrient status properties under tree stands, and they influence one another.

6.2.1 Interrelationships between Measures of Plant Biomass Parameters and Soil Physical Properties.

6.2.2 TESTING OF HYPOTHESIS

H1: There is a positive relationship between plant biomass characteristics and soil properties under the isolated tree stands and the adjoining rainforest.

Correlation analysis technique was employed to examine the relationships between plant biomass parameters and the physical properties of soil under the isolated tree stands and the adjoining rainforest. The results of the analyses are presented in tables 6.1 – 6.4 respectively. The results revealed that plant biomass parameters are positively correlated with some physical properties of the soils. This indicates that there exist some relationships between the biomass parameters and the soil physical properties.

Table 6.1 shows the results of correlations analysis between plant biomass parameters and some physical properties of both the topsoil and subsoil under the stands of Indian almond trees. The observed correlations between plant biomass parameters and some physical properties of the topsoil showed weak relationships in many pairs of the variables. However, there are significant relationships between tree diameters and silt compositions as well as the water holding capacity of the soil under the stands of Indian almond; with p-values as 0.052 and 0.020 respectively. Therefore, tree diameters are significantly correlated with silt composition, as well as the water holding capacity of the topsoil under Indian almond.

The results of correlation analysis between plant biomass parameters and some physical properties of the subsoil under the stands of Indian almond trees are also presented in table 6.1. The observed correlations revealed that relationships exist between many pairs of the variables. There are significant relationships between the tree heights and soil properties such as silt and clay; tree diameters and water holding capacity of the soil; tree crown area and the compositions of silt and clay respectively. Therefore, plant biomass parameters of the isolated stands of Indian almond are significantly correlated with some physical properties of the subsoil underneath the tree stands.

Table 6.1: Relationships between plant biomass parameters and some physical properties of the soil under *Terminalia catappa* (Indian almond)

Soil Layers	Plant biomass parameters	Soil Variables					
		Total porosity	**Percentage Sand**	**Percentage Silt**	**Percentage Clay-sized fractions**	**Bulk density**	**Water holding capacity**
Topsoil	Pearson correlation:						
	Tree height	0.119	0.134	-0.058	-0.064	-0.118	0.001
	Diameter	-0.203	-0.344	-0.436*	0.426	0.203	-0.535*
	Crown area	0.044	0.121	-0.093	-0.040	-0.044	-0.077
	Sig. (1-tailed):						
	Tree height	0.337	0.317	0.418	0.410	0.338	0.500
	Diameter	0.234	0.105	0.052	0.057	0.235	0.020
	Crown area	0.438	0.334	0.371	0.444	0.438	0.392
Subsoil	Pearson correlation:						
	Tree height	0.119	-0.106	-0.445*	0.462*	0.068	-0.186
	Diameter	-0.086	-0.023	0.120	-0.116	0.209	-0.524*
	Crown area	-0.032	-0.081	-0.465*	0.478*	0.172	-0.272
	Sig. (1-tailed):						
	Tree height	0.336	0.354	0.048	0.042	0.404	0.253
	Diameter	0.381	0.468	0.335	0.341	0.227	0.022
	Crown area	0.456	0.387	0.040	0.036	0.269	0.163

*** Significant at the 0.05 level**

Table 6.2: Relationships between plant biomass parameters and some physical properties of the soil under *Mangifera indica* (mango)

Soil Layers	Plant biomass parameters	Soil Variables					
		Total porosity	**Percentage Sand**	**Percentage Silt**	**Percentage Clay-sized fractions**	**Bulk density**	**Water holding capacity**
Topsoil	Pearson correlation:						
	Tree height	0.119	-0.391	0.352	0.215	-0.117	0.274
	Diameter	-0.085	-0.088	0.064	0.112	0.089	-0.281
	Crown area	-0.143	-0.458*	0.344	0.544*	0.144	0.497*
	Sig. (1-tailed):						
	Tree height	0.337	0.075	0.099	0.221	0.339	0.162
	Diameter	0.382	0.378	0.410	0.345	0.376	0.155
	Crown area	0.306	0.043	0.105	0.018	0.304	0.030
Subsoil	Pearson correlation:						
	Tree height	-0.001	-0.043	-0.112	-0.106	-0.022	0.342
	Diameter	-0.038	-0.091	-0.208	0.058	0.055	-0.386
	Crown area	-0.212	0.097	-0.350	-0.002	0.200	0.461*
	Sig. (1-tailed):						
	Tree height	0.499	0.440	0.346	0.354	0.468	0.106
	Diameter	0.447	0.374	0.228	0.418	0.422	0.077
	Crown area	0.224	0.365	0.101	0.497	0.238	0.042

*** Significant at the 0.05 level**

Table 6.2 shows the results of correlations analysis between plant biomass parameters and some physical properties of the soil under the stands of mango trees. The observed correlations some physical properties of the topsoil and plant biomass parameters revealed that weak relationships exist in many pairs of the variables. However, there are significant correlations observed in the relationships between the tree crown areas and soil properties such as sand, clay and water holding capacity. This shows that the area covered by tree crowns has effect on soil physical properties underneath. The soil properties outside tree crown areas could vary from those under tree crown areas due to the direct contributions and nutrient returns to the soil within the tree crown areas.

The results of correlations analysis between plant biomass parameters and some physical properties of the subsoil under the stands of Mango trees are also presented in table 6.2. Like the relationships between plant biomass parameters and some physical properties of the topsoil under Mango tree stands, the observed correlations showed weak and negative relationships in many pairs of the variables. However, only water holding capacity of the soil is significantly correlated with tree crown area. This shows that the area covered by tree crown has effect on soil water holding capacity.

Table 6.3 shows the results of correlations between plant biomass parameters and some physical properties of the soil under the isolated stands of Avocado pear trees. Significant correlations were observed in the relationships between the pairs of tree height and topsoil physical properties such as sand and clay, with p-values of 0.036 and 0.003 respectively; tree crown area and soil properties such as total porosity and bulk density, with p-values of 0.035 and 0.036 respectively.

The results of correlation analysis between plant biomass parameters and some physical properties of the subsoil under the stands of Avocado pear trees are also presented in table 6.3. The observed correlations revealed that there are significant correlations observed in the relationships between tree height and silt composition of the soil, with p-value of 0.009. Therefore, only tree height shows a significant relationship, and with only the silt compositions of the subsoil.

Table 6.3: Relationships between plant biomass parameters and some physical properties of the soil under *Persea gratissima* (avocado pear)

Soil Layers	Plant biomass parameters	Soil Variables					
		Total porosity	Percentage Sand	Percentage Silt	Percentage Clay-sized fractions	Bulk density	Water holding capacity
Topsoil	Pearson correlation:						
	Tree height	0.072	0.478*	-0.281	-0.665*	-0.070	0.111
	Diameter	0.250	0.251	-0.206	-0.153	-0.251	0.139
	Crown area	0.480*	0.287	-0.313	0.087	-0.478*	0.014
	Sig. (1-tailed):						
	Tree height	0.400	0.036	0.155	0.003	0.402	0.347
	Diameter	0.184	0.184	0.231	0.294	0.184	0.311
	Crown area	0.035	0.150	0.128	0.378	0.036	0.480
Subsoil	Pearson correlation:						
	Tree height	-0.262	0.158	-0.600*	-0.060	0.260	0.303
	Diameter	0.155	0.143	-0.086	-0.025	-0.156	-0.132
	Crown area	0.127	-0.272	0.049	0.181	-0.129	0.050
	Sig. (1-tailed):						
	Tree height	0.173	0.287	0.009	0.416	0.175	0.136
	Diameter	0.290	0.305	0.381	0.464	0.289	0.319
	Crown area	0.326	0.163	0.431	0.259	0.324	0.419

*** Significant at the 0.05 level**

Table 6.4: Relationships between plant biomass parameters and some physical properties of the soil under adjoining rainforest

Soil Layers	Plant biomass parameters	Soil Variables					
		Total porosity	Percentage Sand	Percentage Silt	Percentage Clay-sized fractions	Bulk density	Water holding capacity
Topsoil	Pearson correlation:						
	Tree height	-0.241	0 .041	-0.176	0.066	0.238	0.511*
	Diameter	-0.058	-0.241	0.350	0.148	0.058	-0.228
	Sig. (1-tailed):						
	Tree height	0.193	0.443	0.265	0.407	0.197	0.026
	Diameter	0.418	0.193	0.100	0.300	0.418	0.207
Subsoil	Pearson correlation:						
	Tree height	-0.175	-0.099	0.137	0.021	0.175	0.552*
	Diameter	-0.149	-0.553*	-0.600*	0.577*	0.150	-0.090
	Sig. (1-tailed):						
	Tree height	0.267	0.367	0.313	0.470	0.267	0.017
	Diameter	0.298	0.016	0.009	0.012	0.297	0.376

*** Significant at the 0.05 level**

Table 6.4 shows the results of correlation analysis between plant biomass parameters and some physical properties of the soil in the adjoining rainforest. The biomass parameters are tree height and diameters, while the soil physical properties are total porosity, sand, silt, clay, bulk density and water holding capacity. The observed relationships show that there are positive correlations between the biomass parameters and the topsoil physical properties. However, the correlations were only significant between tree heights and water holding capacity. This significant level was observed where the correlation is 0.52 and p-value is 0.026 respectively. Therefore there is a significant relationship between tree height and water holding capacity of the topsoil in the adjoining rainforest at the 5% confidence level.

The results of correlation analysis between plant biomass parameters and some physical properties of the subsoil in the adjoining rainforest are presented in table 6.4. The biomass parameters are tree height and diameters, while the soil physical properties are total porosity, sand, silt, clay, bulk density and water holding capacity. The observed relationships show that there are positive correlations between the biomass parameters and the soil physical properties. However, the correlations were significant between tree heights and water holding capacity, with p-value of 0.017; between tree diameters and soil properties such as sand, silt and clay, with p-values of 0.016, 0.009 and 0.012 respectively. Therefore there are significant relationships between biomass parameters of the tree stands in the adjoining rainforest and some physical properties of the subsoil at the 5% confidence levels.

6.2.3 Interrelationships between Plant Biomass Parameters and Soil Nutrient Status Characteristics

This section presents the correlation analysis of the interrelationships between the measures of plant biomass parameters and nutrient status characteristics of the soils under the isolated tree stands. Positive correlations were observed between pairs of variables for all the isolated tree stands and the adjoining rainforest. The levels of interrelationships appeared similar in comparing between the isolated tree stands and the adjoining rainforest, thus indicating that in the process of nutrient cycling, biomass parameters of the isolated tree stands as well as those of the adjoining rainforest contribute to the nutrient status characteristics of the soil. CEC and organic matter were more positively correlated with the biomass parameters in the isolated tree stands than in the adjoining rainforest. This could be attributed to the effect of isolation which makes litter accumulation higher in the adjoining rainforest than under the isolated tree stands. However, the observed levels of relationships for phosphorus and magnesium appear similar in both the isolated tree stands and the adjoining rainforest.

6.2.4 TESTING OF HYPOTHESIS

H1: There is a positive relationship between plant biomass characteristics and soil properties under the isolated tree stands and the adjoining rainforest.

In order to test the hypothesis, the correlation analysis technique was employed to examine the relationships between plant biomass parameters and the nutrient status characteristics of soil under the isolated tree stands and the adjoining rainforest. The results of the analyses are presented in tables 6.5 – 6.8 respectively. The results revealed that plant biomass parameters are positively correlated with soil nutrient status characteristics. This indicates that soil nutrient status characteristics are related with the biomass parameters of tree stands. Therefore, the stated hypothesis is accepted.

Table 6.5 shows the results of correlation analysis between plant biomass parameters and some nutrient status characteristics of the soil under Indian almond. The observed relationships show that there are positive correlations between the biomass parameters and the topsoil nutrient status characteristics. Tree height is significantly correlated with calcium with a p-value of 0.029; tree crown area is significantly correlated with calcium and potassium with p-values of 0.053 and 0.054 respectively. Therefore there are significant relationships between biomass parameters of the isolated stands of Indian almond and some soil nutrient status characteristics of the topsoil underneath the tree stands at the 5% level of confidence.

The results of correlation analysis between plant biomass parameters and some nutrient status characteristics of the subsoil under Indian almond are also presented in table 6.5. The observed relationships show that there are both positive correlations between the biomass parameters and the subsoil nutrient status characteristics.

Table 6.5: Relationships between plant biomass parameters and nutrient status characteristics of soil under *Terminalia catappa* (Indian almond)

Soil Layers	**Plant biomass parameters**	**Soil Variables**							
		Organic matter	Total nitrogen	Phosphorus	Calcium	Sodium	Magnesium	Potassium	C.E.C
Topsoil	Pearson correlation:								
	Tree height	-0.127	-0.028	0.242	0.499*	0.019	-0.244	-0.320	-0.175
	Diameter	-0.020	-0.284	0.126	-0.017	0.129	-0.153	-0.206	-0.160
	Crown area	-0.189	0.021	0.302	0.435*	0.024	-0.281	-0.429*	-0.226
	Sig. (1-tailed):								
	Tree height	0.327	0.460	0.193	0.029	0.473	0.190	0.123	0.267
	Diameter	0.471	0.153	0.328	0.476	0.323	0.294	0.231	0.284
	Crown area	0.250	0.470	0.137	0.053	0.467	0.155	0.054	0.209
Subsoil	Pearson correlation:								
	Tree height	-0.220	-0.125	0.306	0.249	0.235	-0.274	-0.382	0.031
	Diameter	-0.002	-0.045	0.265	-0.242	-0.006	0.250	-0.328	-0.050
	Crown area	-0.072	0.043	-0.310	0.231	-0.072	-0.153	0.275	0 .090
	Sig. (1-tailed):								
	Tree height	0.216	0.329	0.134	0.186	0.200	0.162	0.080	0.456
	Diameter	0.498	0.437	0.170	0.193	0.491	0.184	0.116	0.430
	Crown area	0.399	0.440	0.130	0.204	0.399	0.293	0.161	0.375

*** Significant at the 0.05 level**

However, the correlations are not significant at the 5% level of confidence. Therefore, there is no significant relationship between the biomass parameters of the isolated stands of Indian almond and the subsoil nutrient status characteristics underneath the tree stands.

Table 6.6 shows the results of correlation analysis between plant biomass parameters and some nutrient status characteristics of the soil under the isolated stands of Mango trees. The observed relationships show that there are positive correlations between the biomass parameters and the topsoil nutrient status characteristics. However, the correlations are significant between tree height and C.E.C' with p-value of 0.042; between tree crown area and Mg and C.E.C with p-values of 0.038 and 0.025 respectively. Therefore there are significant relationships between biomass parameters of the isolated stands of mango trees and some soil nutrient status characteristics of the topsoil underneath the tree stands at the 5% levels of confidence.

The results of correlation analysis between plant biomass parameters and some nutrient status characteristics of the subsoil under the isolated stands of mango trees are presented in table 6.6. The observed relationships show that there are positive correlations between the biomass parameters and the soil nutrient status characteristics. However, no correlation was found to be significant at the 5% confidence level, between the pairs of the biomass parameters of the isolated tree stands and the soil nutrient status characteristics underneath the tree stands. The p-values for all the pairs of relationships are higher than the 0.05 confidence level. Therefore there is no significant relationship between biomass parameters of the isolated stands of Mango trees and soil nutrient status characteristics underneath the tree stands at the 5% levels of confidence.

Table 6.6: Relationships between plant biomass parameters and nutrient status characteristics of the soil under *Mangifera indica* (mango)

Soil Layers	**Plant biomass parameters**	**Soil Variables**							
		Organic matter	Total nitrogen	Phosphorus	Calcium	Sodium	Magnesium	Potassium	C.E.C
Topsoil	Pearson correlation:								
	Tree height	0.326	0.126	-0.110	0.410	-0.171	0.398	0.241	0.459*
	Diameter	-0.068	-0.116	-0.091	-0.106	0.079	0.173	0.323	0.098
	Crown area	0.126	-0.006	0.016	0.408	0.047	0.472*	0.133	0.515*
	Sig. (1-tailed):								
	Tree height	0.118	0.328	0.348	0.064	0.271	0.071	0.193	0.042
	Diameter	0.405	0.340	0.373	0.353	0.390	0.269	0.120	0.365
	Crown area	0.327	0.491	0.477	0.066	0.434	0.038	0.318	0.025
Subsoil	Pearson correlation:								
	Tree height	0.182	-0.021	-0.003	-0.078	-0.244	0.381	-0.184	0.147
	Diameter	-0.294	-0.075	-0.041	-0.097	-0.183	-0.078	0.258	-0.127
	Crown area	0.005	-0.008	0.080	0.044	0.014	0.608*	-0.198	0.399
	Sig. (1-tailed):								
	Tree height	0.258	0.471	0.496	0.392	0.190	0.081	0.255	0.300
	Diameter	0.144	0.395	0.443	0.365	0.257	0.391	0.176	0.327
	Crown area	0.493	0.489	0.388	0.438	0.480	0.008	0.240	0.070

*** Significant at the 0.05 level**

Table 6.7: Relationships between plant biomass parameters and nutrient status characteristics of the soil under *Persea gratissima* (avocado pear)

Soil Layers	Plant biomass parameters	Soil Variables							
		Organic matter	Total nitrogen	Phosphorus	Calcium	Sodium	Magnesium	Potassium	C.E.C
Topsoil	Pearson correlation:								
	Tree height	0.011	0.044	-0.217	-0.091	-0.026	-0.168	0.108	-0.222
	Diameter	0.284	-0.007	0.478*	0.463*	-0.056	0.012	0.005	0.342
	Crown area	0.010	-0.103	0.228	0.365	0.100	0.090	0.409	0.365
	Sig. (1-tailed):								
	Tree height	0.484	0.438	0.219	0.374	0.464	0.275	0.351	0.213
	Diameter	0.152	0.490	0.036	0.041	0.422	0.482	0.492	0.106
	Crown area	0.486	0.357	0.207	0.091	0.362	0.375	0.065	0.091
Subsoil	Pearson correlation:								
	Tree height	-0.126	0.218	0.164	-0.102	-0.361	0.207	-0.162	0.049
	Diameter	-0.445*	-0.202	0.409	0.096	0.188	-0.157	0.053	-0.036
	Crown area	-0.490*	-0.380	0.027	0.124	0.121	-0.110	0.514*	0.016
	Sig. (1-tailed):								
	Tree height	0.327	0.218	0.279	0.358	0.093	0.229	0.282	0.432
	Diameter	0.048	0.235	0.065	0.367	0.251	0.288	0.425	0.450
	Crown area	0.032	0.081	0.462	0.330	0.333	0.348	0.025	0.478

*** Significant at the 0.05 level**

Table 6.7 shows the results of correlation analysis between plant biomass parameters and nutrient status characteristics of the soil under the isolated stands of Avocado pear trees. The observed relationships show that there are positive correlations between the biomass parameters and the topsoil nutrient status characteristics. However, the correlations are only significant between tree diameter and P and Ca, with p-values of 0.036 and 0.041 respectively. The relationships between the pairs of tree height and tree crown area and the soil nutrient status characteristics are not significant at the 5% confidence levels.

The results of correlation analysis between plant biomass parameters and some nutrient status characteristics of the subsoil under the isolated stands of Avocado pear trees are presented in table 6.7. The observed relationships show that there are positive correlations between the biomass parameters of the tree stands and the soil nutrient status characteristics. Tree diameter is significantly correlated with soil organic matter, with a p-value of 0.048; while the tree crown area is significantly correlated with soil organic matter and potassium with p-values of 0.032 and 0.025 respectively. This shows that there are significant positive relationships between the biomass parameters of the isolated stands of Avocado pear and the soil nutrient status characteristics underneath the tree stands at the 5% levels of confidence.

Table 6.8 shows the results of correlation analysis between plant biomass parameters and some nutrient status characteristics of the soil in the adjoining rainforest. The observed relationships show that there are positive correlations between the biomass parameters of the tree stands and the topsoil nutrient status characteristics. Tree height is significantly correlated with P and Mg with p-values of 0.017 and 0.051 respectively. This shows that there are significant positive relationships between the biomass parameters of tree stands in the adjoining rainforest and soil nutrient status characteristics underneath at the 5% levels of confidence.

The results of correlation analysis between plant biomass parameters and some nutrient status characteristics of the subsoil in the adjoining rainforest are presented in table 6.8. The observed relationships show that there are positive correlations between the biomass parameters of the tree stands and the soil nutrient status characteristics. Tree height is significantly correlated with P, with p-value of 0.010; while tree diameter is

Table 6.8: Relationships between plant biomass parameters and nutrient status characteristics of the soil under the adjoining rainforest

Soil Layers	**Plant biomass parameters**	**Soil Variables**							
		Organic matter	Total nitrogen	Phosphorus	Calcium	Sodium	Magnesium	Potassium	C.E.C
Topsoil	Pearson correlation:								
	Tree height	0.069	-0.144	0.547*	-0.416	-0.053	0.439*	-0.221	-0.349
	Diameter	-0.205	-0.055	0.069	-0.099	0.276	0.012	-0.121	-0.095
	Crown area								
	Sig. (1-tailed):								
	Tree height	0.404	0.304	0.017	0.061	0.425	0.051	0.214	0.101
	Diameter	0.232	0.423	0.403	0.363	0.160	0.483	0.334	0.368
	Crown area								
Subsoil	Pearson correlation:								
	Tree height	0.000	-0.076	0.592*	-0.261	0.113	0.138	-0.320	-0.126
	Diameter	-0.273	-0.047	-0.341	0.267	0.586*	0.566*	0.247	0.558*
	Crown area								
	Sig. (1-tailed):								
	Tree height	0.449	0.393	0.010	0.174	0.345	0.312	0.122	0.327
	Diameter	0.163	0.434	0.107	0.168	0.011	0.014	0.187	0.015
	Crown area								

*** Significant at the 0.05 level**

significantly correlated with Na, Mg and C.E.C, with p-values of 0.011, 0.014 and 0.015 respectively. This shows that there are significant positive relationships between the biomass parameters of tree stands in the adjoining rainforest and soil nutrient status characteristics underneath at the 5% levels of confidence.

6.2.5 Relationship between Soil Organic Matter and Measures of Plant Biomass Parameters: Step-Wise Multiple Regression Analysis

This section presents the step-wise multiple regression analysis between the soil organic matter and measures of plant biomass parameters, in response to the research question regarding the relationship between soil organic matter and plant biomass parameters in the different sample sites. Indeed, this section is set to confirm the observed levels of correlations between the variables, and to assess the overall significance of the regression model by investigating the contributions of each variable to the general regression model.

Table 6.9 shows the results of step-wise multiple regression analysis between soil organic matter and plant biomass parameters of the topsoil under the isolated tree stands and the adjoining rainforest. The overall regression models for the avocado pear, mango, Indian almond and adjoining rainforest are significant at 0.436, 0.577, 0.844 and 0.765; while the F-values are 0.984, 0.698, 0.272 and 0.274 respectively. Therefore, there is no significant relationship between soil organic matter and plant biomass parameters at the 0.05 levels of confidence. This implies that each of the biomass parameters cannot account for the organic matter status under the tree stands at the 5% confidence levels (appendices 6.1 – 6.4). Under the avocado pear, mango, Indian almond and the adjoining rainforest, the Adjusted R square values show that our models account for 0.3%, 7.1%, 18.5% and 11.6% respectively. In all the sample sites, the standardized Beta coefficients show that tree heights have more effect on soil organic matter than the tree diameters and crown covers respectively. The t-values and significant p-values (appendices 6.1 - 6.4) also show that each of the biomass parameters did not contribute significantly at the 0.05 level of confidence to the soil organic matter under the tree stands.

Table 6.9: Step-wise Multiple regression results for organic matter and measures of plant biomass parameters in the topsoil

Sample sites	Dependent variables	Independent variables	Model	Sum of squares	df	Mean square	Adjusted R square	Std Beta Coeff	F	Sig.
Avocado pear	organic matter	Tree height	Regression	1.687	3	0.562	0.003	0.358	0.984	0.436
		Diameter	Residual	6.287	11	0.572		0.220		
		Crown area	Total	7.974	14			0.231		
Mango	organic matter	Tree height	Regression	0.522	3	0.174	0.071	0.591	0.698	0.577
		Diameter	Residual	2.777	11	0.252		-0.081		
		Crown area	Total	3.299	14			-0.316		
Indian almond	organic matter	Tree height	Regression	0.090	3	0.030	0.185	0.626	0.272	0.844
		Diameter	Residual	1.218	11	0.111		0.051		
		Crown area	Total	1.308	14			-0.790		
Adjoining rainforest	organic matter	Tree height	Regression	0.210	2	0.105	0.116	0.040	0.274	0.765
		Diameter	Residual	4.595	12	0.383		-0.200		
			Total	4.805	14					

Table 6.10: Step-wise Multiple regression results for organic matter and measures of plant biomass parameters in the subsoil

Sample sites	Dependent variables	Independent variables	Model	Sum of squares	df	Mean square	Adjusted R square	Std Beta Coeff	F	Sig.
Avocado pear	organic matter	Tree height Diameter Crown area	Regression Residual Total	0.378 0.942 1.320	3 11 14	0.126 0.086	0.092	0.163 -0.337 -0.321	1.472	0.276
Mango	organic matter	Tree height Diameter Crown area	Regression Residual Total	0.339 1.720 2.060	3 11 14	0.113 0.156	-0.063	0.428 -0.300 -0.239	0.724	0.559
Indian almond	organic matter	Tree height Diameter Crown area	Regression Residual Total	0.047 0.840 0.887	3 11 14	0.016 0.076	-0.206	-0.416 -0.048 0.205	0.204	0.892
Adjoining rainforest	organic matter	Tree height Diameter	Regression Residual Total	0.442 5.372 5.814	2 12 14	0.221 0.448	-0.078	-0.040 -0.279	0.494	0.622

Table 6.10 shows the results of step-wise multiple regression analysis between soil organic matter and plant biomass parameters of the subsoils under the isolated tree stands and the adjoining rainforest. The overall regression models for the avocado pear, mango, Indian almond and adjoining rainforest are insignificant. Therefore, there is no significant relationship between soil organic matter and plant biomass parameters at the 0.05 levels of confidence thus, confirms the observed levels of correlations between the organic matter and the biomass parameters.

Under the avocado pear, mango, Indian almond and the adjoining rainforest, the adjusted R square values show that our models account for 9.2%, 6.3%, 20.6% and -7.8% of the variance respectively. In all the sample sites, the standardized Beta coefficients show that tree heights have more effect on soil organic matter than the tree diameters and crown covers respectively. The t-values and significant p-values (appendices 6.5 – 6.8) also show that each of the biomass parameters did not contribute significantly at the 0.05 levels to the soil organic matter under the tree stands.

The soil organic matter relationship with plant biomass parameters is much lower in the subsoils than in the topsoil. This is as to be expected because, organic matter concentrations in the soil is higher in the topsoil than in the subsoils. Therefore, in the process of nutrient cycling, organic matter composition of the soil is not highly dependent on all the plant biomass parameters. As will be observed in the next chapter, the production of litter under tree stands is affected by tree heights. Very tall trees tend to have their litter spread further from the base of tree stands than relatively shorter tree stands. However, litterfall has been observed to be a major source of nutrient return to the soil in nutrient cycling.

6.3 Relationships between Litter Production and Soil Properties under Tree Stands

Litter production by the isolated tree stands and adjoining rainforest are related with the soil physical and nutrient properties underneath.

6.3.1 Relationships between Litter Production and Physical Properties of the Topsoil under Tree Stands

Results of the correlation analyses presented in table 6.11 shows that litter production is positively correlated with soil physical properties such as porosity, water holding capacity, bulk density and silt composition; and negatively correlated with sand and clay compositions respectively.

The observed correlations are stronger with porosity and water holding capacity. Under the stands of Indian almond, mango, avocado pear and rainforest, litter production is positively correlated with porosity, water holding capacity, bulk density and silt. The correlations between litter production on the one hand, and porosity, water holding capacity, bulk density and silt on the other hand, for Indian almond are 0.651, 0.559, 0.151 and 0.477. The corresponding correlations for mango are 0.462, 0.634, 0.008 and 0.358; those for avocado pear are 0.746, 0.719, 0.147 and 0.291; while correlations for the rainforest are 0.819, 0.825, 0.235 and 0.380 respectively.

6.3.2 Relationships between Litter Production and Nutrient Characteristics of the Topsoil under Tree Stands

Table 6.12 shows the correlation values between litter production and nutrient status of the topsoil under the stands of Indian almond, mango, avocado pear and the adjoining rainforest respectively. All the nutrient status characteristics of the soils under the isolated tree stands and adjoining rainforest are positively correlated with litter production.

Apart from the observed lower correlation values for calcium and magnesium, the relationship between litter production and other soil nutrient characteristics are strongly and positively correlated. Therefore, litter production by the isolated tree stands and the adjoining rainforest has implications on the soil nutrient characteristics underneath the tree stands.

Table 6.11: Pearson's bivariate correlations between litter production and physical characteristics of the topsoil

Sites	Litter variable	Soil Variables					
		Porosity	Water holding Capacity	Bulk density	Sand	Silt	Clay
Indian almond	Litter production	0.651*	0.559*	0.151	-0.148	0.477*	-0.313
Mango	Litter production	0.462*	0.634*	0.008	-0.204	0.358	-0.221
Avocado pear	Litter production	0.746*	0.719*	0.147	-0.182	0.291	-0.082
Rainforest	Litter production	0.819*	0.825*	0.235	-0.439*	0.380	-0.417*

*** Significant at the 0.05 level**

Table 6.12: Pearson's bivariate correlations between litter production and nutrient characteristics of the topsoil

Sites	Litter variable	Soil Nutrient Elements							
		Organic matter	N	P	Ca	Na	Mg	K	CEC
Indian almond	Litter production	0.817*	0.804*	0.901*	0.301	0.754*	0.418*	0.742*	0.822*
Mango	Litter production	0.798*	0.846*	0.892*	0.413*	0.641*	0.375	0.876*	0.814*
Avocado pear	Litter production	0.746*	0.802*	0.878*	0.483*	0.840*	0.215	0.641*	0.761*
Rainforest	Litter production	0.868*	0.841*	0.905*	0.498*	0.886*	0.487*	0.897*	0.881*

*** Significant at the 0.05 level**

6.4 Relationships between Soil Nutrients and Nutrients Returned in Litterfall, Throughfall and Stemflow

Litterfall, throughfall and stemflow contribute to soil nutrient status by returning nutrient elements to the soil from the aboveground tree stands. The levels of correlation vary due possibly to variations in the returns of nutrient elements to the soil by the litterfall, throughfall and stemflow respectively.

6.4.1 TESTING OF HYPOTHESIS

H1: Nutrient elements returned to the soil through litterfall, throughfall and stemflow are positively correlated with soil nutrient elements underneath the tree stands.

In order to test the hypothesis, the Pearson's bivariate correlation analysis was employed to examine the relationships between nutrients returned in litterfall and soil nutrients; nutrients returned in throughfall and soil nutrients; nutrients returned in stemflow and soil nutrients respectively. The results of the analyses are presented in tables 6.13 – 6.15. The results revealed that soil nutrient elements are positively correlated with nutrients returned via litterfall, throughfall and stemflow. Therefore, the stated hypothesis is accepted.

6.4.2 Relationships between Soil Nutrients and Nutrients Returned in Litterfall

The nutrient content of litterfall is correlated with the nutrient elements of the topsoil under the isolated tree stands and the adjoining rainforest. From table 6.13, apart from the observed negative relationships between potassium and nitrogen, potassium and phosphorus as well as potassium and sodium respectively, the correlation values show that there are positive relationships between the nutrient content of litterfall and the soil nutrient elements under the isolated tree stands and the adjoining rainforest.

N, P and Na returned in litterfall are positively correlated with the topsoil nutrient properties except K in the topsoil. While Ca and Mg returned in litterfall are positively correlated with all the topsoil nutrient elements, K in litterfall is positively correlated with only K, Ca and Mg in the topsoil respectively. Generally, the observed levels of correlation between nutrients returned in litterfall and the nutrient elements in the topsoil shows that litterfall contributes to soil nutrient status. Therefore, relationships exist between the nutrients returned in litterfall and the nutrient elements in the topsoil underneath the tree stands.

Table 6.13: Correlations between nutrients returned in litterfall and topsoil nutrient properties.

Sites	Litter nutrient elements	Soil Nutrient Elements					
		Nitrogen	Phosphorus	Potassium	Calcium	Sodium	Magnesium
Indian almond	Nitrogen	0.936*	0.602*	-0.168	0.617*	0.500*	0.160
Mango		0.882*	0.473*	-0.043	0.731*	0.615*	0.367
Avocado pear		0.814*	0.540*	-0.019	0.778*	0.404	0.536*
Rainforest		0.921*	0.595*	-0.004	0.692*	0.566*	0.547*
Indian almond	Phosphorus	0.659*	0.869*	-0.450*	0.345	0.564*	0.367
Mango		0.300	0.808*	-0.690*	0.535*	0.289	0.326
Avocado pear		0.470*	0.909*	-0.586*	0.574*	0.621*	0.463*
Rainforest		0.421*	0.925*	-0.991*	0.607*	0.782*	0.327
Indian almond	Potassium	-0.397	-0.836*	0.901*	0.782*	-0.993*	0.642*
Mango		-0.981*	-0.906*	0.902*	0.682*	-0.952*	0.305
Avocado pear		-0.826*	-0.951*	0.867*	0.757*	-0.916*	0.618*
Rainforest		-0.811*	-0.910*	0.894*	0.478v	-0.276	0.666*
Indian almond	Calcium	0.549*	0.626*	0.764*	0.866*	0.526*	0.284
Mango		0.595*	0.086	0.682*	0.882*	0.500*	0.366
Avocado pear		0.161	0.432*	0.437*	0.895*	0.345	0.463*
Rainforest		0.325	0.505*	0.508*	0.914*	0.329	0.419*
Indian almond	Sodium	0.682*	0.602*	-0.968*	0.934*	0.921*	0.160
Mango		0.500*	0.784*	-0.997*	0.705*	0.897*	0.121
Avocado pear		0.449*	0.682*	-0.448*	0.416*	0.810*	0.089
Rainforest		0.642*	0.047	-0.999*	0.680*	0.940*	0.143
Indian almond	Magnesium	0.194	0.332	0.384	0.558*	0.434*	0.834*
Mango		0.500*	0.349	0.564*	0.261	0.596*	0.803*
Avocado pear		0.176	0.446*	0.423*	0.507*	0.359	0.884*
Rainforest		0.216	0.488*	0.546*	0.575*	0.626*	0.929*

*** Significant at the 0.05 level**

6.4.3 Relationships between Soil Nutrients and Nutrients Returned via Rainwash

Throughfall and stemflow return nutrient elements to the soil, and therefore contribute to soil nutrient status under tree stands. The amount of nutrient elements returned to the soil via throughfall and stemflow are positively correlated with the soil nutrient elements under the tree stands.

From table 6.14, the returns of N, P, K, Ca, Na and Mg to the soil via throughfall are positively correlated with the N, P, K, Ca, Na and Mg in the soil. However, it was also observed that the returns of K and Mg are negatively correlated with Na in the soil while Na returned to the soil via throughfall is negatively correlated with K and Mg in the soil underneath tree stands.

Nutrient elements returned to the soil through stemflow also have positive correlations with the nutrient elements in the soil underneath tree stands (Table 6.15). Therefore, stemflow contributes to soil nutrient status under tree stands.

Table 6.14: Correlations between nutrients returned in throughfall and topsoil nutrient properties.

Sites	Throughfal lnutrient elements	Soil Nutrient Elements					
		Nitrogen	Phosphorus	Potassium	Calcium	Sodium	Magnesium
Indian almond	Nitrogen	0.714*	0.501*	0.401*	0.541*	0.321	0.101
Mango		0.660*	0.354	0.513*	0.512*	0.513*	0.213
Avocado pear		0.602*	0.324	0.517*	0.558*	0.326	0.238
Rainforest		0.701*	0.373	0.616*	0.436*	0.425*	0.213
Indian almond	Phosphorus	0.536*	0.646*	0.534*	0.231	0.436*	0.311
Mango		0.310	0.606*	0.734*	0.346	0.143	0.234
Avocado pear		0.316	0.717*	0.624*	0.321	0.512*	0.231
Rainforest		0.264	0.703*	0.904*	0.435*	0.439*	0.312
Indian almond	Potassium	0.373	0.343	0.674*	0.7540*	-0.865*	0.453*
Mango		0.832*	0.453*	0.745*	0.453*	-0.456*	0.213
Avocado pear		0.568*	0.582*	0.723*	0.702*	-0.354	0.543*
Rainforest		0.679*	0.693*	0.824*	0.478*	-0.288	0.442*
Indian almond	Calcium	0.463*	0.625*	0.664*	0.839*	0.543*	0.201
Mango		0.505*	0.146	0.482*	0.843*	0.500*	0.322
Avocado pear		0.121	0.552*	0.337	0.827*	0.345	0.423*
Rainforest		0.365	0.605*	0.608*	0.914*	0.329	0.317
Indian almond	Sodium	0.569*	0.402*	-0.768*	0.904*	0.721*	-0.110
Mango		0.430*	0.684*	-0.897*	0.672*	0.897*	-0.101
Avocado pear		0.445*	0.582*	-0.438*	0.418*	0.810*	-0.084
Rainforest		0.603*	0.147	-0.879*	0.643*	0.740*	-0.122
Indian almond	Magnesium	0.104	0.232	0.354	0.564*	-0.434*	0.647*
Mango		0.512*	0.249	0.584*	0.269	-0.596*	0.764*
Avocado pear		0.106	0.236	0.443*	0.543*	-0.359	0.664*
Rainforest		0.138	0.457*	0.246	0.587*	-0.426*	0.901*

*** Significant at the 0.05 level**

Table 6.15: Correlations between nutrients returned in stemflow and topsoil nutrient properties.

Sites	Throughfal lnutrient elements	Soil Nutrient Elements					
		Nitrogen	Phosphorus	Potassium	Calcium	Sodium	Magnesium
Indian almond	Nitrogen	0.314	0.301	0.210	0.326	0.325	0.112
Mango		0.360	0.254	0.213	0.376	0.413*	0.123
Avocado pear		0.202	0.214	0.324	0.458*	0.226	0.234
Rainforest		0.301	0.253	0.322	0.434*	0.525*	0.201
Indian almond	Phosphorus	0.236	0.336	-0.411*	0.243	0.351	0.211
Mango		0.110	0.346	-0.403	0.325	0.143	0.235
Avocado pear		0.216	0.417*	-0.433*	0.303	0.412*	0.201
Rainforest		0.164	0.503*	-0.561*	0.412*	0.434*	0.314
Indian almond	Potassium	0.173	-0.343	-0.442*	0.654*	-0.815*	-0.423*
Mango		0.332	-0.253	-0.512*	0.324	-0.436*	-0.213
Avocado pear		0.468*	-0.482*	-0.214*	0.543*	-0.334	-0.523*
Rainforest		0.579*	-0.543*	-0.553*	0.412*	-0.258	-0.342
Indian almond	Calcium	0.363	0.425*	0.334	0.534*	0.343	0.261
Mango		0.405*	0.146	0.233	0.534*	0.520*	0.432*
Avocado pear		0.111	0.402	0.122	0.134	0.435*	0.233
Rainforest		0.215	0.515*	0.312	0.167	0.319	0.247
Indian almond	Sodium	0.369	0.312	-0.867*	0.674*	0.561*	-0.512*
Mango		0.230	0.454*	-0.878*	0.453*	0.567*	-0.416*
Avocado pear		0.345	0.422*	-0.723	0.442*	0.460*	-0.589*
Rainforest		0.503*	0.137	-0.956*	0.436*	0.650*	-0.648*
Indian almond	Magnesium	0.100	0.202	-0.231	0.236	-0.634*	0.584*
Mango		0.312	0.244	-0.502*	0.212	-0.546*	0.574*
Avocado pear		0.116	0.231	-0.412*	0.434*	-0.554*	0.463*
Rainforest		0.121	0.346	-0.243	0.365	-0.613*	0.658*

*** Significant at the 0.05 level**

6.5 Discussions

The findings on relationships between biomass parameters of tree stands and the soil properties suggest that the greater the biomass of the standing plant as evidenced by the larger sizes of trees, the higher the nutrient status of the soil. This relationship is to be expected because in the process of nutrient cycling, tree plants depend on soil nutrient for their growth and development. Biomass parameters such as diameter and crown areas are significantly positively correlated with soil physical and nutrient properties. This implies that the biomass parameters enhance the capacity of tree stands to regenerate soil fertility as they develop. For reasons explained earlier, the correlations between the parameters of the nutrient status of the subsoil and biomass characteristics are lower than those of the topsoil. The general pattern of correlations in both the topsoil and subsoil is similar. Significant positive relationships exist between soil particle size distribution and the biomass parameters of the tree stands. The positive relationships are more associated with silt and clay sized particles while sand particles are negatively correlated. Sand is chemically inert and does not contribute towards soil nutrient adsorbing and water retaining capacities. Sites which are sandy are therefore poor in nutrients and have a low power to provide adequate moisture for plant growth. The more positive relationship with clay should be expected since the clay content of the soil enhances its power to retain plant nutrients and to hold moisture. However, since silt is chemically inert, it is possible that the silt content of the soil affects plant growth by improving soil water holding capacity and porosity by aiding particle aggregation. In the process of nutrient cycling, plant biomass parameters affect the physical and nutrient status characteristics of the soil underneath. Therefore, there is a positive relationship between plant biomass and soil characteristics in the different sample sites.

Measures of plant biomass parameters such as tree height, tree diameter and tree crown areas tend to be more significantly correlated with some of the soil variables than others. This is reflected in the correlation coefficients between the measures of plant biomass parameters and some physical properties of the soil. The plant biomass is positively correlated with soil particle size distribution, water holding capacity and bulk density. However, the relationship between plant biomass parameters and some physical properties of soil are similar amongst the different isolated tree stands and the adjoining rainforest. The correlations are mostly weak with respect to the stated hypothesis. However, significant relationships exist in correlations between biomass parameters and soil particle size distributions. Tree height correlated significantly with water holding capacity in the adjoining rainforest, while tree diameter and crown areas are significantly correlated with water holding capacity under Indian almond and mango tree stands respectively. Therefore, there are variations in the pairs of correlated variables which appeared significant at the 0.05 level. Improvements in soil physical conditions such as water holding capacity and total porosity make it possible for the plants to grow bigger. Increase in vegetation crown area and the size of individual tree stand encourages the build-up of organic matter in the soil.

There is a build-up of soil organic matter and nutrient elements in the soils under the isolated tree stands and the adjoining rainforest, which can be attributed to the impact of litterfall and rainwash directly under the tree canopies. This result is in contrast with findings reported in a study by Akpokodlje and Aweto (2007) on the effects of *Gliricidia sepium* on soil underneath in southern Nigeria, where no significant build-up of organic matter and nutrients was observed owing to frequent cultivation and burning. In the study area, the levels of soil organic matter are lower under isolated tree stands than the adjoining rainforest which expectedly is at equilibrium level. The implication of the observed lower organic matter status under the isolated tree stands could be due to the effect of isolation, while the tree stands in the adjoining rainforest are in strata. Litterfall and litter returns under tree stands in the adjoining rainforest may have been enhanced by other trees that are closer. The study also revealed that litterfall is an important source of nutrient return to the soil in the process of nutrient cycling. The correlation results show that the pairs of litter production and each nutrient elements returned to the soil are related. There is a strong positive relationship between litter production and the returns of nutrient elements through litterfall, soil characteristics; and also between soil nutrient elements and nutrient returns in litterfall, throughfall and stemflow respectively.

CHAPTER SEVEN

SUMMARY, CONCLUSIONS, POLICY IMPLICATIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

This study examines nutrient cycling under isolated exotic tree stands in the rainforest ecosystem. It focused on the processes of nutrients return from the aboveground tree stands to the soil underneath. In order to account for the factors that could affect these processes of nutrients return, the biomass characteristics of the tree stands such as the tree height, tree diameter, tree crown area, basal area and litter production were examined. The study was conducted using the conceptual framework of nutrient cycling and tree influence circle. These concepts as earlier stated, were so chosen because the process of nutrient cycling has impact on the soil, while different tree species have been observed to have varying effects on the soils underneath tree stands.

In order to achieve the stated aim and objectives of the research, the study involved direct field data collection on biomass parameters of the tree stands, as well as on the processes of nutrients return to the soil in nutrient cycling. Data collected on the stemflow, throughfall and litterfall were subjected to laboratory analyses, the results of which were further subjected to statistical analyses in order to give answers to the research questions and the stated hypotheses. This chapter therefore presents the summary of findings, conclusions, policy implications, recommendations and suggestions for further research.

7.2 SUMMARY OF FINDINGS

The findings of this study revealed that there are differences in the biomass characteristics of the tree stands. Tree biomass and litter production of isolated tree stands are lower than those of the adjoining rainforest. They are generally lowest in the stands of avocado pear. While some of the biomass parameters of Indian almond and mango tree stands are within the same mean ranges with the adjoining rainforest, those of the avocado pear stands are much lower. However, the mean tree heights are higher in the adjoining rainforest than in the isolated tree stands. The much lower height of the isolated tree stands may have assisted in concentrating litter directly under the tree canopies, thereby enhancing the organic matter status of the soils under the tree stands.

Litter production was observed to vary amongst the tree stands, and also with the seasons of the year, and has been attributed to variations in the phonological changes which occur in the different tree species. However, the correlations between litter production and nutrient returns through litterfall vary, and show that there are positive relationships between litter production and nutrients returned in litterfall. The relationship between plant biomass characteristics and soil properties varied amongst the isolated tree stands and the adjoining rainforest. Litterfall and litter production were observed to contribute to soil organic matter and nutrient elements in the soil underneath the isolated tree stands and the adjoining rainforest. Organic matter is lower under the isolated tree stands than in the soil under the adjoining rainforest.

The study further revealed that stemflow, throughfall and litterfall are important sources of nutrients return to the soil in the process of nutrient cycling. Litterfall returned more nutrients to the soil than throughfall and stemflow. All precipitation events were observed to leach nutrient elements from the canopies and trunks of tree stands to the soils underneath; however, stemflow and throughfall have higher concentrations of dissolved nutrients than the incident rainfall. The concentrations and returns of nutrient elements varied amongst the isolated tree stands and the adjoining rainforest. This implies that in nutrient cycling, the returns of nutrient elements vary with tree species. Apart from magnesium returns in stemflow which is higher in the stands of mango trees than in incident rainfall, the highest concentration and returns of each nutrient element to the soil was via throughfall, followed by stemflow and the lowest in incident rainfall (Throughfall > stemflow > incident rainfall). Therefore, throughfall returned more nutrients to the soil than stemflow.

The observed variations in the concentrations and returns of nutrient elements amongst the sample sites were all significant, except in the returns of magnesium through stemflow. The returns of nutrient elements to the soil via litterfall and rainwash varied with the seasons of the year. The return of nutrient elements in stemflow is highest during the peak of rainy season while the highest returns of nutrient elements via throughfall were observed during the early and late rains. The early and late rains wash down the aerosols (which contain nutrient elements) captured by the tree leaves and branches to the soil underneath.

For both the concentrations and returns of nutrient elements, stemflow and throughfall varied significantly at the 0.05 levels of confidence for all the isolated tree stands and the adjoining rainforest. Although there are marked variations in the concentrations and returns of nutrient elements through rainwash for the isolated tree stands and the adjoining rainforest, the observed amounts of nutrient elements returned to the soil by the isolated tree stands in comparison with the adjoining rainforest showed a close similarity. Generally, it was observed that throughfall is the major pathway of potassium return to the soil, while it is relatively a minor vector for N, P, and Na.

The concentrations and returns of nutrient elements in litterfall also vary amongst the isolated tree stands and the adjoining rainforest. The concentrations and returns of all the nutrient elements were highest in the adjoining rainforest except for the concentrations of potassium and the returns of potassium and phosphorus which was higher in Indian almond stands respectively. Calcium flux in litterfall is high while a lower concentration of nutrient elements was observed during the wet season. Seasonal variations in the concentrations and returns of nutrient elements to the soil were observed for the isolated tree stands and the adjoining rainforest. The concentrations and returns of nutrient elements were higher in the months with higher litter production. While the highest returns of nutrients by Indian almond and mango tree stands was observed in the rainy months, avocado pear stands returned the highest nutrient elements in the dry season.

7.3 CONCLUSIONS

The findings in this study have revealed that litterfall, throughfall and stemflow return nutrients to the soil, and are therefore important sources of nutrients return to the soil in the process of nutrient cycling. The concentrations and returns of nutrient elements to the soil vary with tree species as well as the seasons of the year. The observed trends in seasonal variations in litter production could be attributed to the variations in phonological changes among the tree species. While there is a positive relationship between litter production and the returns of nutrient elements via litterfall, it was also observed that the returns of nutrient elements are correlated with the soil nutrient elements under the isolated tree stands and the adjoining rainforest respectively. Nutrient elements were leached from the canopies and trunks of tree stands to the soils underneath during the precipitation events. Therefore, from the results of this study, it can be concluded that litterfall and rainwash return nutrient elements from the isolated stands of *T. cattapa, P. gratissima* and *M. indica* to the soil underneath, and thus help to improve the soil nutrient status underneath the tree stands in the process of nutrient cycling. It is therefore suggested that, growing the tree crops should be encouraged in the deforested rainforest so as to maintain the soils of the ecosystem.

7.4 POLICY IMPLICATIONS AND RECOMMENDATIONS

The findings of this study revealed that there are significant differences in the biomass characteristics of tree stands, as well as the soil properties under them. The different isolated tree species exert varying influence on the soils of the rainforest ecosystem. Litter production varied amongst the isolated tree stands, and also with the seasons of the year. Litterfall and rainwash contribute to soil nutrient status in the process of nutrient cycling. However, while the returns of these nutrient elements vary amongst the isolated tree species, they also vary with the seasons of the year. Also, the observed relationships between litter production and soil organic matter revealed that, litter production, unlike the characteristics of tree stands (tree height, diameter and crown area), contribute to the organic matter status of the soils under the tree stands. Based on these established facts, the following are the policy implications and recommendations of the study.

Nutrients returned through litterfall and rainwash from the isolated exotic tree stands contribute to soil nutrient composition. It is therefore, suggested that the growing of *T. cattapa, P. gratissima* and *M. indica* should be encouraged in deforested rainforest so as to maintain the soils of the ecosystem.

It is possible to incorporate these tree species into the agroforestry practice in the region. By this, the government through the appropriate ministries and commissions should see the need to establish agroforestry scheme geared towards the growing of such exotics like the *T. cattapa, P. gratissima* and *M. indica*. This is necessary for their ecological effects in terms of soil nutrient improvement and providing tree cover in deforested areas. The efforts of both the government and the inhabitants of the concerned environment are needed to manage and maintain our degraded rainforest ecosystem.

The need to adopt the plantations of these exotics in the deforested rainforest is recommended, to ensure sustainable tree stands in the ecosystem. By applying the integrated environmental management approach therefore, plantations of these exotics trees can be managed by the inhabitants. Where possible, the growing of annuals within the exotic tree plants at the early stage of production to check weed should be adopted. If the local inhabitants are involved in this environmental management exercise, problems like fire can be checked and controlled. Before now, these tree plants were grown for their shade and fruits around the farmsteads and in settlements. The practice of continuously conserving the existing ones while new ones are grown should be encouraged. This approach will be effective due to the benefits for the producer of such tree crops.

Furthermore, since these exotic tree species return nutrient elements to the soil underneath, thereby improving soil nutrient status and sustaining soil productivity in the rainforest environment, they are therefore recommended as farm trees.

7.5 SUGGESTIONS FOR FURTHER RESEARCH

This study focused on aspect of nutrient cycling by considering the processes of nutrients return from the aboveground biomass of isolated exotic tree stands to the soils underneath. It is important to point out here that the research findings reported in this study have been based on the side–by–side comparison of the characteristics of tree stands and soils under them on the one hand, and comparisons of the processes of nutrients return to the soil by the different species of isolated tree stands on the other hand. The rate of litter decomposition amongst the tree species was not determined. Therefore, it is essential to suggest that furher studies on nutrient cycling in the rainforest ecosystem should be carried out to investigate the rate of litter decomposition and nutrients uptake by the isolated exotic tree stands.

Further studies should be conducted to examine the effects of these exotic tree stands on crop productivity within the rainforest environment. This is necessary to ascertain the relevance of incorporating the exotic trees into farmland areas.

It is also suggested that further studies should be carried out to examine the contributions of individual tree species of the rainforest origin to soil fertility restoration.

This study did not focus on the aspect of nutrient uptake from soil by the isolated exotic tree stands. It is important for further studies to be carried out to ascertain the extent to which the exotic trees take nutrients from to soil.

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APPENDICES

Appendix 4.1: Summary of the Results Obtained By One-Way Analysis Of Variance amongst the Isolated Tree Stands and the Adjoining Rainforest: Tree Characteristics

Vegetation characteristics	**Groups**	**Sum of squares**	**d/f**	**Mean square**	**F**	**Table F**	**Decision**
Tree height	Between	5163.711	3	1721.237	1525.650	2.84	Significant
	Within	63.179	56	1.128			
	Total	5226.890	59				
Tree diameter	Between	1.683	3	0.561	113.377	2.84	Significant
	Within	0.277	56	0.005			
	Total	1.960	59				
Tree crown area	Between	48124.652	2	24062.326	279.098	3.23	Significant
	Within	3621.011	42	86.215			
	Total	51745.663	44				
Tree basal areas	Between	2.220	3	.740	141.594	2.84	significant
	Within	.293	56	.005			
	Total	2.513	59				

*** Significant at F > critical table F (2.84 and 3.23) at the 0.05 level**

Appendix 4.2: Multiple comparisons using the Least Square Difference (LSD) test: Tree Heights

Multiple Comparisons

Dependent Variable: species
LSD

(I) sites	(J) sites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.50133	.38785	.201	-1.2783	.2756
	3.00	3.14600*	.38785	.000	2.3690	3.9230
	4.00	-20.29800*	.38785	.000	-21.0750	-19.5210
2.00	1.00	.50133	.38785	.201	-.2756	1.2783
	3.00	3.64733*	.38785	.000	2.8704	4.4243
	4.00	-19.79667*	.38785	.000	-20.5736	-19.0197
3.00	1.00	-3.14600*	.38785	.000	-3.9230	-2.3690
	2.00	-3.64733*	.38785	.000	-4.4243	-2.8704
	4.00	-23.44400*	.38785	.000	-24.2210	-22.6670
4.00	1.00	20.29800*	.38785	.000	19.5210	21.0750
	2.00	19.79667*	.38785	.000	19.0197	20.5736
	3.00	23.44400*	.38785	.000	22.6670	24.2210

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Indian almond, Mango, Avocado pear, and Adjoining rainforest respectively

Appendix 4.3: Multiple comparisons using the LSD test: Tree Diameters

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.30867*	.02569	.000	-.3601	-.2572
	3.00	.11733*	.02569	.000	.0659	.1688
	4.00	.07933*	.02569	.003	.0279	.1308
2.00	1.00	.30867*	.02569	.000	.2572	.3601
	3.00	.42600*	.02569	.000	.3745	.4775
	4.00	.38800*	.02569	.000	.3365	.4395
3.00	1.00	-.11733*	.02569	.000	-.1688	-.0659
	2.00	-.42600*	.02569	.000	-.4775	-.3745
	4.00	-.03800	.02569	.145	-.0895	.0135
4.00	1.00	-.07933*	.02569	.003	-.1308	-.0279
	2.00	-.38800*	.02569	.000	-.4395	-.3365
	3.00	.03800	.02569	.145	-.0135	.0895

*. The mean difference is significant at the .05 level.

1,2,3 and 4 represent Indian almond, Mango, Avocado pear, and Adjoining rainforest respectively

Appendix 4.4: Multiple Comparisons using the LSD test: Tree Crown areas

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-15.42667*	3.39047	.000	-22.2689	-8.5844
	3.00	60.36000*	3.39047	.000	53.5178	67.2022
2.00	1.00	15.42667*	3.39047	.000	8.5844	22.2689
	3.00	75.78667*	3.39047	.000	68.9444	82.6289
3.00	1.00	-60.36000*	3.39047	.000	-67.2022	-53.5178
	2.00	-75.78667*	3.39047	.000	-82.6289	-68.9444

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent Indian almond, Mango and Avocado pear respectively

Appendix 4.5: Multiple Comparisons using the LSD test: Tree Basal areas

Multiple Comparisons

Dependent Variable: basal
LSD

(I) sites	(J) sites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.38933*	.02640	.000	-.4422	-.3365
	3.00	.08733*	.02640	.002	.0345	.1402
	4.00	.05933*	.02640	.029	.0065	.1122
2.00	1.00	.38933*	.02640	.000	.3365	.4422
	3.00	.47667*	.02640	.000	.4238	.5295
	4.00	.44867*	.02640	.000	.3958	.5015
3.00	1.00	-.08733*	.02640	.002	-.1402	-.0345
	2.00	-.47667*	.02640	.000	-.5295	-.4238
	4.00	-.02800	.02640	.293	-.0809	.0249
4.00	1.00	-.05933*	.02640	.029	-.1122	-.0065
	2.00	-.44867*	.02640	.000	-.5015	-.3958
	3.00	.02800	.02640	.293	-.0249	.0809

*. The mean difference is significant at the .05 level.

1,2,3 and 4 represent Indian almond, Mango, Avocado pear, and Adjoining rainforest respectively

Appendix 4.6: Multiple comparisons using the LSD test: Topsoil Porosity

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-4.29333*	1.19585	.001	-6.6889	-1.8978
	3.00	-2.64667*	1.19585	.031	-5.0422	-.2511
	4.00	-8.66667*	1.19585	.000	-11.0622	-6.2711
2.00	1.00	4.29333*	1.19585	.001	1.8978	6.6889
	3.00	1.64667	1.19585	.174	-.7489	4.0422
	4.00	-4.37333*	1.19585	.001	-6.7689	-1.9778
3.00	1.00	2.64667*	1.19585	.031	.2511	5.0422
	2.00	-1.64667	1.19585	.174	-4.0422	.7489
	4.00	-6.02000*	1.19585	.000	-8.4156	-3.6244
4.00	1.00	8.66667*	1.19585	.000	6.2711	11.0622
	2.00	4.37333*	1.19585	.001	1.9778	6.7689
	3.00	6.02000*	1.19585	.000	3.6244	8.4156

*. The mean difference is significant at the .05 level.

1,2,3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.7: Multiple comparison using the LSD test: Subsoil Porosity

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.10000	1.46665	.946	-2.8380	3.0380
	3.00	2.08000	1.46665	.162	-.8580	5.0180
	4.00	-2.96667*	1.46665	.048	-5.9047	-.0286
2.00	1.00	-.10000	1.46665	.946	-3.0380	2.8380
	3.00	1.98000	1.46665	.182	-.9580	4.9180
	4.00	-3.06667*	1.46665	.041	-6.0047	-.1286
3.00	1.00	-2.08000	1.46665	.162	-5.0180	.8580
	2.00	-1.98000	1.46665	.182	-4.9180	.9580
	4.00	-5.04667*	1.46665	.001	-7.9847	-2.1086
4.00	1.00	2.96667*	1.46665	.048	.0286	5.9047
	2.00	3.06667*	1.46665	.041	.1286	6.0047
	3.00	5.04667*	1.46665	.001	2.1086	7.9847

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.8: Multiple comparison using the LSD test: Topsoil Bulk density

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.11400*	.03168	.001	.0505	.1775
	3.00	.07000*	.03168	.031	.0065	.1335
	4.00	.22933*	.03168	.000	.1659	.2928
2.00	1.00	-.11400*	.03168	.001	-.1775	-.0505
	3.00	-.04400	.03168	.170	-.1075	.0195
	4.00	.11533*	.03168	.001	.0519	.1788
3.00	1.00	-.07000*	.03168	.031	-.1335	-.0065
	2.00	.04400	.03168	.170	-.0195	.1075
	4.00	.15933*	.03168	.000	.0959	.2228
4.00	1.00	-.22933*	.03168	.000	-.2928	-.1659
	2.00	-.11533*	.03168	.001	-.1788	-.0519
	3.00	-.15933*	.03168	.000	-.2228	-.0959

*. The mean difference is significant at the .05 level.

1, 2,3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.9 Multiple comparison using the LSD test: Subsoil Bulk density

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.00600	.03877	.878	-.0837	.0717
	3.00	-.04467	.03877	.254	-.1223	.0330
	4.00	.07867*	.03877	.047	.0010	.1563
2.00	1.00	.00600	.03877	.878	-.0717	.0837
	3.00	-.03867	.03877	.323	-.1163	.0390
	4.00	.08467*	.03877	.033	.0070	.1623
3.00	1.00	.04467	.03877	.254	-.0330	.1223
	2.00	.03867	.03877	.323	-.0390	.1163
	4.00	.12333*	.03877	.002	.0457	.2010
4.00	1.00	-.07867*	.03877	.047	-.1563	-.0010
	2.00	-.08467*	.03877	.033	-.1623	-.0070
	3.00	-.12333*	.03877	.002	-.2010	-.0457

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.10: Multiple comparison using the LSD test: Water holding capacity in Topsoil

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-2.02667*	.92473	.033	-3.8791	-.1742
	3.00	-3.20667*	.92473	.001	-5.0591	-1.3542
	4.00	-7.71333*	.92473	.000	-9.5658	-5.8609
2.00	1.00	2.02667*	.92473	.033	.1742	3.8791
	3.00	-1.18000	.92473	.207	-3.0325	.6725
	4.00	-5.68667*	.92473	.000	-7.5391	-3.8342
3.00	1.00	3.20667*	.92473	.001	1.3542	5.0591
	2.00	1.18000	.92473	.207	-.6725	3.0325
	4.00	-4.50667*	.92473	.000	-6.3591	-2.6542
4.00	1.00	7.71333*	.92473	.000	5.8609	9.5658
	2.00	5.68667*	.92473	.000	3.8342	7.5391
	3.00	4.50667*	.92473	.000	2.6542	6.3591

*. The mean difference is significant at the .05 level.

1,2,3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.11: Multiple comparison using the LSD test: Water holding capacity in subsoil

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.39333	.95593	.682	-2.3083	1.5216
	3.00	-.77333	.95593	.422	-2.6883	1.1416
	4.00	-7.94000*	.95593	.000	-9.8550	-6.0250
2.00	1.00	.39333	.95593	.682	-1.5216	2.3083
	3.00	-.38000	.95593	.692	-2.2950	1.5350
	4.00	-7.54667*	.95593	.000	-9.4616	-5.6317
3.00	1.00	.77333	.95593	.422	-1.1416	2.6883
	2.00	.38000	.95593	.692	-1.5350	2.2950
	4.00	-7.16667*	.95593	.000	-9.0816	-5.2517
4.00	1.00	7.94000*	.95593	.000	6.0250	9.8550
	2.00	7.54667*	.95593	.000	5.6317	9.4616
	3.00	7.16667*	.95593	.000	5.2517	9.0816

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.12: Multiple comparison using the LSD test: Topsoil Sand composition

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	2.87133*	.74073	.000	1.3875	4.3552
	3.00	-.24600	.74073	.741	-1.7299	1.2379
	4.00	-1.68467*	.74073	.027	-3.1685	-.2008
2.00	1.00	-2.87133*	.74073	.000	-4.3552	-1.3875
	3.00	-3.11733*	.74073	.000	-4.6012	-1.6335
	4.00	-4.55600*	.74073	.000	-6.0399	-3.0721
3.00	1.00	.24600	.74073	.741	-1.2379	1.7299
	2.00	3.11733*	.74073	.000	1.6335	4.6012
	4.00	-1.43867	.74073	.057	-2.9225	.0452
4.00	1.00	1.68467*	.74073	.027	.2008	3.1685
	2.00	4.55600*	.74073	.000	3.0721	6.0399
	3.00	1.43867	.74073	.057	-.0452	2.9225

*. The mean difference is significant at the .05 level.

1,2,3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.13: Multiple comparison using the LSD test: Subsoil Sand composition

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	1.74333*	.60975	.006	.5219	2.9648
	3.00	-.27533	.60975	.653	-1.4968	.9461
	4.00	1.13333	.60975	.068	-.0881	2.3548
2.00	1.00	-1.74333*	.60975	.006	-2.9648	-.5219
	3.00	-2.01867*	.60975	.002	-3.2401	-.7972
	4.00	-.61000	.60975	.321	-1.8315	.6115
3.00	1.00	.27533	.60975	.653	-.9461	1.4968
	2.00	2.01867*	.60975	.002	.7972	3.2401
	4.00	1.40867*	.60975	.025	.1872	2.6301
4.00	1.00	-1.13333	.60975	.068	-2.3548	.0881
	2.00	.61000	.60975	.321	-.6115	1.8315
	3.00	-1.40867*	.60975	.025	-2.6301	-.1872

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.14: Multiple comparison using the LSD test: Topsoil Silt composition

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-3.03267*	.59683	.000	-4.2283	-1.8371
	3.00	2.12333*	.59683	.001	.9277	3.3189
	4.00	3.19333*	.59683	.000	1.9977	4.3889
2.00	1.00	3.03267*	.59683	.000	1.8371	4.2283
	3.00	5.15600*	.59683	.000	3.9604	6.3516
	4.00	6.22600*	.59683	.000	5.0304	7.4216
3.00	1.00	-2.12333*	.59683	.001	-3.3189	-.9277
	2.00	-5.15600*	.59683	.000	-6.3516	-3.9604
	4.00	1.07000	.59683	.078	-.1256	2.2656
4.00	1.00	-3.19333*	.59683	.000	-4.3889	-1.9977
	2.00	-6.22600*	.59683	.000	-7.4216	-5.0304
	3.00	-1.07000	.59683	.078	-2.2656	.1256

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.15: Multiple comparison using the LSD test: Subsoil Silt composition

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-1.47400*	.53643	.008	-2.5486	-.3994
	3.00	-1.44667*	.53643	.009	-2.5213	-.3721
	4.00	.86133	.53643	.114	-.2133	1.9359
2.00	1.00	1.47400*	.53643	.008	.3994	2.5486
	3.00	.02733	.53643	.960	-1.0473	1.1019
	4.00	2.33533*	.53643	.000	1.2607	3.4099
3.00	1.00	1.44667*	.53643	.009	.3721	2.5213
	2.00	-.02733	.53643	.960	-1.1019	1.0473
	4.00	2.30800*	.53643	.000	1.2334	3.3826
4.00	1.00	-.86133	.53643	.114	-1.9359	.2133
	2.00	-2.33533*	.53643	.000	-3.4099	-1.2607
	3.00	-2.30800*	.53643	.000	-3.3826	-1.2334

*. The mean difference is significant at the .05 level.

1,2,3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.16: Multiple comparison using the LSD test: Topsoil Clay composition

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.16133	.55159	.771	-.9436	1.2663
	3.00	-1.87733*	.55159	.001	-2.9823	-.7724
	4.00	-1.50867*	.55159	.008	-2.6136	-.4037
2.00	1.00	-.16133	.55159	.771	-1.2663	.9436
	3.00	-2.03867*	.55159	.000	-3.1436	-.9337
	4.00	-1.67000*	.55159	.004	-2.7750	-.5650
3.00	1.00	1.87733*	.55159	.001	.7724	2.9823
	2.00	2.03867*	.55159	.000	.9337	3.1436
	4.00	.36867	.55159	.507	-.7363	1.4736
4.00	1.00	1.50867*	.55159	.008	.4037	2.6136
	2.00	1.67000*	.55159	.004	.5650	2.7750
	3.00	-.36867	.55159	.507	-1.4736	.7363

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.17: Multiple comparison using the LSD test: Subsoil Clay composition

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-1.06933	.82218	.199	-2.7164	.5777
	3.00	1.25533	.82218	.132	-.3917	2.9024
	4.00	-2.46133*	.82218	.004	-4.1084	-.8143
2.00	1.00	1.06933	.82218	.199	-.5777	2.7164
	3.00	2.32467*	.82218	.006	.6776	3.9717
	4.00	-1.39200	.82218	.096	-3.0390	.2550
3.00	1.00	-1.25533	.82218	.132	-2.9024	.3917
	2.00	-2.32467*	.82218	.006	-3.9717	-.6776
	4.00	-3.71667*	.82218	.000	-5.3637	-2.0696
4.00	1.00	2.46133*	.82218	.004	.8143	4.1084
	2.00	1.39200	.82218	.096	-.2550	3.0390
	3.00	3.71667*	.82218	.000	2.0696	5.3637

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.18: Multiple comparison using the LSD test: Topsoil organic carbon

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.66267*	.11745	.000	-.8980	-.4274
	3.00	-.54800*	.11745	.000	-.7833	-.3127
	4.00	-1.31667*	.11745	.000	-1.5520	-1.0814
2.00	1.00	.66267*	.11745	.000	.4274	.8980
	3.00	.11467	.11745	.333	-.1206	.3500
	4.00	-.65400*	.11745	.000	-.8893	-.4187
3.00	1.00	.54800*	.11745	.000	.3127	.7833
	2.00	-.11467	.11745	.333	-.3500	.1206
	4.00	-.76867*	.11745	.000	-1.0040	-.5334
4.00	1.00	1.31667*	.11745	.000	1.0814	1.5520
	2.00	.65400*	.11745	.000	.4187	.8893
	3.00	.76867*	.11745	.000	.5334	1.0040

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.19: Multiple comparison using the LSD test: Subsoil organic carbon

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.60000*	.09010	.000	-.7805	-.4195
	3.00	-.52933*	.09010	.000	-.7098	-.3488
	4.00	-1.08267*	.09010	.000	-1.2632	-.9022
2.00	1.00	.60000*	.09010	.000	.4195	.7805
	3.00	.07067	.09010	.436	-.1098	.2512
	4.00	-.48267*	.09010	.000	-.6632	-.3022
3.00	1.00	.52933*	.09010	.000	.3488	.7098
	2.00	-.07067	.09010	.436	-.2512	.1098
	4.00	-.55333*	.09010	.000	-.7338	-.3728
4.00	1.00	1.08267*	.09010	.000	.9022	1.2632
	2.00	.48267*	.09010	.000	.3022	.6632
	3.00	.55333*	.09010	.000	.3728	.7338

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.20: Multiple comparison using the LSD test: Topsoil organic matter

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-1.13600*	.20346	.000	-1.5436	-.7284
	3.00	-.93600*	.20346	.000	-1.3436	-.5284
	4.00	-2.26333*	.20346	.000	-2.6709	-1.8557
2.00	1.00	1.13600*	.20346	.000	.7284	1.5436
	3.00	.20000	.20346	.330	-.2076	.6076
	4.00	-1.12733*	.20346	.000	-1.5349	-.7197
3.00	1.00	.93600*	.20346	.000	.5284	1.3436
	2.00	-.20000	.20346	.330	-.6076	.2076
	4.00	-1.32733*	.20346	.000	-1.7349	-.9197
4.00	1.00	2.26333*	.20346	.000	1.8557	2.6709
	2.00	1.12733*	.20346	.000	.7197	1.5349
	3.00	1.32733*	.20346	.000	.9197	1.7349

*. The mean difference is significant at the .05 level.

1,2,3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.21: Multiple comparison using the LSD test: Subsoil organic matter

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-1.03000*	.15492	.000	-1.3403	-.7197
	3.00	-.91200*	.15492	.000	-1.2223	-.6017
	4.00	-1.86600*	.15492	.000	-2.1763	-1.5557
2.00	1.00	1.03000*	.15492	.000	.7197	1.3403
	3.00	.11800	.15492	.449	-.1923	.4283
	4.00	-.83600*	.15492	.000	-1.1463	-.5257
3.00	1.00	.91200*	.15492	.000	.6017	1.2223
	2.00	-.11800	.15492	.449	-.4283	.1923
	4.00	-.95400*	.15492	.000	-1.2643	-.6437
4.00	1.00	1.86600*	.15492	.000	1.5557	2.1763
	2.00	.83600*	.15492	.000	.5257	1.1463
	3.00	.95400*	.15492	.000	.6437	1.2643

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.22: Multiple comparison using the LSD test: Topsoil total nitrogen

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.03467	.02883	.234	-.0924	.0231
	3.00	-.08400*	.02883	.005	-.1417	-.0263
	4.00	-.14333*	.02883	.000	-.2011	-.0856
2.00	1.00	.03467	.02883	.234	-.0231	.0924
	3.00	-.04933	.02883	.093	-.1071	.0084
	4.00	-.10867*	.02883	.000	-.1664	-.0509
3.00	1.00	.08400*	.02883	.005	.0263	.1417
	2.00	.04933	.02883	.093	-.0084	.1071
	4.00	-.05933*	.02883	.044	-.1171	-.0016
4.00	1.00	.14333*	.02883	.000	.0856	.2011
	2.00	.10867*	.02883	.000	.0509	.1664
	3.00	.05933*	.02883	.044	.0016	.1171

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.23: Multiple comparison using the LSD test: Subsoil total nitrogen

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.00533	.01504	.724	-.0355	.0248
	3.00	-.03333*	.01504	.031	-.0635	-.0032
	4.00	-.08133*	.01504	.000	-.1115	-.0512
2.00	1.00	.00533	.01504	.724	-.0248	.0355
	3.00	-.02800	.01504	.068	-.0581	.0021
	4.00	-.07600*	.01504	.000	-.1061	-.0459
3.00	1.00	.03333*	.01504	.031	.0032	.0635
	2.00	.02800	.01504	.068	-.0021	.0581
	4.00	-.04800*	.01504	.002	-.0781	-.0179
4.00	1.00	.08133*	.01504	.000	.0512	.1115
	2.00	.07600*	.01504	.000	.0459	.1061
	3.00	.04800*	.01504	.002	.0179	.0781

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.24: Multiple comparison using the LSD test: Topsoil phosphorus

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.33000	1.03243	.750	-2.3982	1.7382
	3.00	-2.10133*	1.03243	.047	-4.1695	-.0331
	4.00	-3.09467*	1.03243	.004	-5.1629	-1.0265
2.00	1.00	.33000	1.03243	.750	-1.7382	2.3982
	3.00	-1.77133	1.03243	.092	-3.8395	.2969
	4.00	-2.76467*	1.03243	.010	-4.8329	-.6965
3.00	1.00	2.10133*	1.03243	.047	.0331	4.1695
	2.00	1.77133	1.03243	.092	-.2969	3.8395
	4.00	-.99333	1.03243	.340	-3.0615	1.0749
4.00	1.00	3.09467*	1.03243	.004	1.0265	5.1629
	2.00	2.76467*	1.03243	.010	.6965	4.8329
	3.00	.99333	1.03243	.340	-1.0749	3.0615

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.25: Multiple comparison using the LSD test: Subsoil phosphorus

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.56800	.49798	.259	-1.5656	.4296
	3.00	-1.38800*	.49798	.007	-2.3856	-.3904
	4.00	-1.35667*	.49798	.008	-2.3562	-.3611
2.00	1.00	.56800	.49798	.259	-.4296	1.5656
	3.00	-.82000	.49798	.105	-1.8176	.1776
	4.00	-.79067	.49798	.118	-1.7882	.2069
3.00	1.00	1.38800*	.49798	.007	.3904	2.3856
	2.00	.82000	.49798	.105	-.1776	1.8176
	4.00	.02933	.49798	.953	-.9682	1.0269
4.00	1.00	1.35867*	.49798	.008	.3611	2.3562
	2.00	.79067	.49798	.118	-.2069	1.7882
	3.00	-.02933	.49798	.953	-1.0269	.9682

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.26: Multiple comparison using the LSD test: Topsoil calcium

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-57.00000	68.82525	.411	-194.8735	80.8735
	3.00	-82.06667	68.82525	.238	-219.9402	55.8069
	4.00	-997.26667*	68.82525	.000	-1135.1402	-859.3931
2.00	1.00	57.00000	68.82525	.411	-80.8735	194.8735
	3.00	-25.06667	68.82525	.717	-162.9402	112.8069
	4.00	-940.26667*	68.82525	.000	-1078.1402	-802.3931
3.00	1.00	82.06667	68.82525	.238	-55.8069	219.9402
	2.00	25.06667	68.82525	.717	-112.8069	162.9402
	4.00	-915.20000*	68.82525	.000	-1053.0735	-777.3265
4.00	1.00	997.26667*	68.82525	.000	859.3931	1135.1402
	2.00	940.26667*	68.82525	.000	802.3931	1078.1402
	3.00	915.20000*	68.82525	.000	777.3265	1053.0735

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.27: Multiple comparison using the LSD test: Subsoil calcium

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-5.93333	28.87477	.838	-63.7764	51.9098
	3.00	-4.80000	28.87477	.869	-62.6431	53.0431
	4.00	-186.00000*	28.87477	.000	-243.8431	-128.1569
2.00	1.00	5.93333	28.87477	.838	-51.9098	63.7764
	3.00	1.13333	28.87477	.969	-56.7098	58.9764
	4.00	-180.06667*	28.87477	.000	-237.9098	-122.2236
3.00	1.00	4.80000	28.87477	.869	-53.0431	62.6431
	2.00	-1.13333	28.87477	.969	-58.9764	56.7098
	4.00	-181.20000*	28.87477	.000	-239.0431	-123.3569
4.00	1.00	186.00000*	28.87477	.000	128.1569	243.8431
	2.00	180.06667*	28.87477	.000	122.2236	237.9098
	3.00	181.20000*	28.87477	.000	123.3569	239.0431

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.28: Multiple comparison using the LSD test: Topsoil magnesium

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-8.00000	15.87476	.616	-39.8010	23.8010
	3.00	-15.26667	15.87476	.340	-47.0676	16.5343
	4.00	-231.46667*	15.87476	.000	-263.2676	-199.6657
2.00	1.00	8.00000	15.87476	.616	-23.8010	39.8010
	3.00	-7.26667	15.87476	.649	-39.0676	24.5343
	4.00	-223.46667*	15.87476	.000	-255.2676	-191.6657
3.00	1.00	15.26667	15.87476	.340	-16.5343	47.0676
	2.00	7.26667	15.87476	.649	-24.5343	39.0676
	4.00	-216.20000*	15.87476	.000	-248.0010	-184.3990
4.00	1.00	231.46667*	15.87476	.000	199.6657	263.2676
	2.00	223.46667*	15.87476	.000	191.6657	255.2676
	3.00	216.20000*	15.87476	.000	184.3990	248.0010

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.29: Multiple comparison using the LSD test: Subsoil magnesium

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-8.66667	13.46829	.523	-35.6469	18.3136
	3.00	-9.26667	13.46829	.494	-36.2469	17.7136
	4.00	-103.33333*	13.46829	.000	-130.3136	-76.3531
2.00	1.00	8.66667	13.46829	.523	-18.3136	35.6469
	3.00	-.60000	13.46829	.965	-27.5802	26.3802
	4.00	-94.66667*	13.46829	.000	-121.6469	-67.6864
3.00	1.00	9.26667	13.46829	.494	-17.7136	36.2469
	2.00	.60000	13.46829	.965	-26.3802	27.5802
	4.00	-94.06667*	13.46829	.000	-121.0469	-67.0864
4.00	1.00	103.33333*	13.46829	.000	76.3531	130.3136
	2.00	94.66667*	13.46829	.000	67.6864	121.6469
	3.00	94.06667*	13.46829	.000	67.0864	121.0469

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.30: Multiple comparison using the LSD test: Topsoil Potassium

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-2.93333	5.15244	.571	-13.2549	7.3882
	3.00	-3.93333	5.15244	.448	-14.2549	6.3882
	4.00	-58.66667*	5.15244	.000	-68.9882	-48.3451
2.00	1.00	2.93333	5.15244	.571	-7.3882	13.2549
	3.00	-1.00000	5.15244	.847	-11.3216	9.3216
	4.00	-55.73333*	5.15244	.000	-66.0549	-45.4118
3.00	1.00	3.93333	5.15244	.448	-6.3882	14.2549
	2.00	1.00000	5.15244	.847	-9.3216	11.3216
	4.00	-54.73333*	5.15244	.000	-65.0549	-44.4118
4.00	1.00	58.66667*	5.15244	.000	48.3451	68.9882
	2.00	55.73333*	5.15244	.000	45.4118	66.0549
	3.00	54.73333*	5.15244	.000	44.4118	65.0549

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.31: Multiple comparison using the LSD test: Subsoil potassium

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	1.80000	2.17628	.412	-2.5596	6.1596
	3.00	-1.40000	2.17628	.523	-5.7596	2.9596
	4.00	-11.20000*	2.17628	.000	-15.5596	-6.8404
2.00	1.00	-1.80000	2.17628	.412	-6.1596	2.5596
	3.00	-3.20000	2.17628	.147	-7.5596	1.1596
	4.00	-13.00000*	2.17628	.000	-17.3596	-8.6404
3.00	1.00	1.40000	2.17628	.523	-2.9596	5.7596
	2.00	3.20000	2.17628	.147	-1.1596	7.5596
	4.00	-9.80000*	2.17628	.000	-14.1596	-5.4404
4.00	1.00	11.20000*	2.17628	.000	6.8404	15.5596
	2.00	13.00000*	2.17628	.000	8.6404	17.3596
	3.00	9.80000*	2.17628	.000	5.4404	14.1596

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.32: Multiple comparison using the LSD test: Topsoil Sodium

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-7.53333*	3.47718	.035	-14.4990	-.5677
	3.00	-8.33333*	3.47718	.020	-15.2990	-1.3677
	4.00	-41.13333*	3.47718	.000	-48.0990	-34.1677
2.00	1.00	7.53333*	3.47718	.035	.5677	14.4990
	3.00	-.80000	3.47718	.819	-7.7656	6.1656
	4.00	-33.60000*	3.47718	.000	-40.5656	-26.6344
3.00	1.00	8.33333*	3.47718	.020	1.3677	15.2990
	2.00	.80000	3.47718	.819	-6.1656	7.7656
	4.00	-32.80000*	3.47718	.000	-39.7656	-25.8344
4.00	1.00	41.13333*	3.47718	.000	34.1677	48.0990
	2.00	33.60000*	3.47718	.000	26.6344	40.5656
	3.00	32.80000*	3.47718	.000	25.8344	39.7656

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.33: Multiple comparison using the LSD test: Subsoil sodium

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	1.20000	1.20449	.323	-1.2129	3.6129
	3.00	-.20000	1.20449	.869	-2.6129	2.2129
	4.00	-8.20000*	1.20449	.000	-10.6129	-5.7871
2.00	1.00	-1.20000	1.20449	.323	-3.6129	1.2129
	3.00	-1.40000	1.20449	.250	-3.8129	1.0129
	4.00	-9.40000*	1.20449	.000	-11.8129	-6.9871
3.00	1.00	.20000	1.20449	.869	-2.2129	2.6129
	2.00	1.40000	1.20449	.250	-1.0129	3.8129
	4.00	-8.00000*	1.20449	.000	-10.4129	-5.5871
4.00	1.00	8.20000*	1.20449	.000	5.7871	10.6129
	2.00	9.40000*	1.20449	.000	6.9871	11.8129
	3.00	8.00000*	1.20449	.000	5.5871	10.4129

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.34: Multiple comparison using the LSD test: Topsoil C.E.C

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.39467	.34963	.264	-1.0951	.3057
	3.00	-.58400	.34963	.100	-1.2844	.1164
	4.00	-7.24533*	.34963	.000	-7.9457	-6.5449
2.00	1.00	.39467	.34963	.264	-.3057	1.0951
	3.00	-.18933	.34963	.590	-.8897	.5111
	4.00	-6.85067*	.34963	.000	-7.5511	-6.1503
3.00	1.00	.58400	.34963	.100	-.1164	1.2844
	2.00	.18933	.34963	.590	-.5111	.8897
	4.00	-6.66133*	.34963	.000	-7.3617	-5.9609
4.00	1.00	7.24533*	.34963	.000	6.5449	7.9457
	2.00	6.85067*	.34963	.000	6.1503	7.5511
	3.00	6.66133*	.34963	.000	5.9609	7.3617

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.35: Multiple comparisons using the LSD test: Subsoil C.E.C

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.09200	.18838	.627	-.4694	.2854
	3.00	-.10267	.18838	.588	-.4800	.2747
	4.00	-1.85467*	.18838	.000	-2.2320	-1.4773
2.00	1.00	.09200	.18838	.627	-.2854	.4694
	3.00	-.01067	.18838	.955	-.3880	.3667
	4.00	-1.76267*	.18838	.000	-2.1400	-1.3853
3.00	1.00	.10267	.18838	.588	-.2747	.4800
	2.00	.01067	.18838	.955	-.3667	.3880
	4.00	-1.75200*	.18838	.000	-2.1294	-1.3746
4.00	1.00	1.85467*	.18838	.000	1.4773	2.2320
	2.00	1.76267*	.18838	.000	1.3853	2.1400
	3.00	1.75200*	.18838	.000	1.3746	2.1294

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.36: Multiple comparisons using the LSD test: Topsoil pH

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.56667*	.18632	.004	.1934	.9399
	3.00	.32667	.18632	.085	-.0466	.6999
	4.00	-.15333	.18632	.414	-.5266	.2199
2.00	1.00	-.56667*	.18632	.004	-.9399	-.1934
	3.00	-.24000	.18632	.203	-.6132	.1332
	4.00	-.72000*	.18632	.000	-1.0932	-.3468
3.00	1.00	-.32667	.18632	.085	-.6999	.0466
	2.00	.24000	.18632	.203	-.1332	.6132
	4.00	-.48000*	.18632	.013	-.8532	-.1068
4.00	1.00	.15333	.18632	.414	-.2199	.5266
	2.00	.72000*	.18632	.000	.3468	1.0932
	3.00	.48000*	.18632	.013	.1068	.8532

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 4.37: Multiple comparisons using the LSD test: Subsoil pH

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	1.02000*	.17963	.000	.6602	1.3798
	3.00	.50667*	.17963	.007	.1468	.8665
	4.00	-.04667	.17963	.796	-.4065	.3132
2.00	1.00	-1.02000*	.17963	.000	-1.3798	-.6602
	3.00	-.51333*	.17963	.006	-.8732	-.1535
	4.00	-1.06667*	.17963	.000	-1.4265	-.7068
3.00	1.00	-.50667*	.17963	.007	-.8665	-.1468
	2.00	.51333*	.17963	.006	.1535	.8732
	4.00	-.55333*	.17963	.003	-.9132	-.1935
4.00	1.00	.04667	.17963	.796	-.3132	.4065
	2.00	1.06667*	.17963	.000	.7068	1.4265
	3.00	.55333*	.17963	.003	.1935	.9132

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Avocado pear, Mango, Indian almond and Adjoining rainforest respectively

Appendix 5.1: Multiple comparisons using the LSD test: Tree Litter production

Multiple Comparisons

Dependent Variable: Sites
LSD

(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	6.51250*	14.60262	.000	-22.9171	35.9421
	3.00	22.81333*	14.60262	.000	-6.6163	52.2430
	4.00	5.73250*	14.60262	.000	-23.6971	35.1621
2.00	1.00	-6.51250*	14.60262	.000	-35.9421	22.9171
	3.00	16.30083	14.60262	.270	-13.1288	45.7305
	4.00	-.78000	14.60262	.958	-30.2096	28.6496
3.00	1.00	-22.81333*	14.60262	.000	-52.2430	6.6163
	2.00	-16.30083	14.60262	.270	-45.7305	13.1288
	4.00	-17.08083*	14.60262	.000	-46.5105	12.3488
4.00	1.00	-5.73250*	14.60262	.000	-35.1621	23.6971
	2.00	.78000	14.60262	.958	-28.6496	30.2096
	3.00	17.08083*	14.60262	.000	-12.3488	46.5105

* .The mean difference is significant at the .05 level

1, 2,3 and 4 represent Indian almond, Mango, Avocado pear, and Adjoining rainforest respectively

Appendix 5.2: Mean Concentrations of Nitrogen in Litterfall in mg/g

Months	Indian Almond	Mango	Avocado pear	Adjoining

	(*Terminalia cattapa*)	(*Mangifera indica*)	(*Persea gratissima*)	Rainforest
Feb	3.98	3.70	3.17	12.05
Mar	4.54	5.62	5.03	15.50
Apr	4.21	7.91	7.25	14.25
May	6.80	7.02	7.01	10.11
Jun	6.68	7.01	7.00	8.87
Jul	7.10	5.81	5.22	8.70
Aug	8.21	3.93	3.64	7.86
Sep	8.19	3.65	3.53	8.02
Oct	8.47	3.91	3.71	8.50
Nov	6.20	3.10	3.10	10.62
Dec	3.15	3.11	3.01	11.00
Jan	2.89	2.64	2.46	12.80
Mean S.D	5.87 2.03	4.78 1.80	4.51 1.74	10.69 2.52

Source: Field work

Appendix 5.3: Mean Concentrations of Phosphorus in Litterfall in mg/g

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	0.46	0.51	0.89	0.94
Mar	0.50	0.77	0.84	0.86
Apr	0.51	0.78	0.70	0.70
May	0.52	0.78	0.57	0.61
Jun	0.83	0.80	0.54	0.54
Jul	0.95	0.61	0.53	0.55
Aug	0.91	0.69	0.56	0.57
Sep	0.92	0.51	0.58	0.58
Oct	0.98	0.43	0.72	0.74
Nov	0.45	0.42	0.67	0.68
Dec	0.49	0.43	0.88	0.89
Jan	0.43	0.48	0.88	0.92
Mean S.D	0.66 0.23	0.60 0.16	0.70 0.14	0.72 0.15

Source: Field work

Appendix 5.4: Mean Concentrations of Potassium in Litterfall in mg/g

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	2.16	2.01	3.12	6.32
Mar	3.72	3.40	4.38	4.40
Apr	5.01	5.98	5.62	5.56
May	6.21	6.01	2.46	2.50
Jun	6.31	4.11	1.76	1.85
Jul	6.10	3.99	1.78	1.87
Aug	7.10	5.01	1.80	1.80
Sep	7.01	3.99	1.84	1.88
Oct	7.24	3.14	2.46	2.62
Nov	3.13	3.02	4.54	4.54
Dec	2.21	2.22	5.12	4.45
Jan	2.18	2.04	6.31	6.43
Mean S.D	4.87 2.06	3.74 1.39	3.43 1.67	3.69 1.81

Source: Field work

Appendix 5.5: Mean Concentrations of Calcium in Litterfall in mg/g

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	4.97	5.86	10.36	12.60
Mar	5.58	7.49	9.34	9.60
Apr	6.41	9.32	8.90	9.00
May	6.62	8.22	8.05	8.10
Jun	8.20	9.47	7.86	7.96
Jul	10.76	8.72	8.04	8.24
Aug	10.12	9.02	7.98	8.00
Sep	11.00	7.01	7.97	7.80
Oct	11.42	5.41	9.12	9.21
Nov	8.00	5.01	9.87	10.20
Dec	5.10	5.02	10.29	12.40
Jan	4.49	5.14	10.20	11.20
Mean S.D	7.72 2.56	7.14 1.79	9.00 1.00	9.53 1.73

Source: Field work

Appendix 5.6: Mean Concentrations of Sodium in Litterfall in mg/g

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	0.25	0.24	0.69	0.77
Mar	0.32	0.32	0.66	0.68
Apr	0.31	0.51	0.46	0.48
May	0.41	0.50	0.39	0.39
Jun	0.46	0.46	0.35	0.36
Jul	0.57	0.46	0.35	0.37
Aug	0.65	0.34	0.38	0.38
Sep	0.62	0.31	0.40	0.40
Oct	0.54	0.24	0.48	0.49
Nov	0.39	0.27	0.61	0.62
Dec	0.22	0.22	0.71	0.71
Jan	0.22	0.22	0.68	0.75
Mean	0.41	0.34	0.51	0.53
S.D	0.16	0.11	0.15	0.16

Source: Field work

Appendix 5.7: Mean Concentrations of Magnesium in Litterfall in mg/g

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	0.98	0.98	3.78	3.80
Mar	1.20	2.10	3.14	3.24
Apr	1.75	3.12	3.11	3.20
May	2.46	2.42	2.82	2.87
Jun	3.55	2.56	2.61	2.62
Jul	3.02	1.01	2.80	2.80
Aug	3.05	2.40	2.70	2.72
Sep	3.08	1.02	2.89	2.98
Oct	3.12	1.11	3.01	3.00
Nov	2.08	1.03	3.60	3.60
Dec	1.96	0.98	3.62	3.64
Jan	0.98	0.99	3.53	3.74
Mean	2.27	1.64	3.13	3.18
S.D	0.91	0.81	0.40	0.42

Source: Field work

Appendix 5.8: Monthly pH values in litterfall

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	4.7	5.0	5.0	4.9
Mar	4.4	4.8	4.9	5.0
Apr	4.3	4.7	5.2	5.3
May	4.2	4.7	5.1	5.2
Jun	4.6	4.8	5.3	5.5
Jul	4.4	5.1	5.2	5.4
Aug	4.8	5.0	5.0	5.3
Sep	4.1	4.9	4.9	5.2
Oct	4.7	5.4	5.1	5.4
Nov	4.6	4.8	5.0	5.1
Dec	4.8	5.3	5.2	5.0
Jan	4.8	5.2	5.1	4.8
Mean	4.53	4.98	5.08	5.18
S.D	0.25	0.23	0.13	0.22

Source: Field work

Appendix 5.9: Multiple comparisons with LSD test: Nitrogen concentrations in litterfall

Multiple Comparisons

Dependent Variable: data
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	2.00	1.08417	.83458	.201	-.5978	2.7662
	3.00	1.35750	.83458	.111	-.3245	3.0395
	4.00	-4.82167*	.83458	.000	-6.5037	-3.1397
2.00	1.00	-1.08417	.83458	.201	-2.7662	.5978
	3.00	.27333	.83458	.745	-1.4087	1.9553
	4.00	-5.90583*	.83458	.000	-7.5878	-4.2238
3.00	1.00	-1.35750	.83458	.111	-3.0395	.3245
	2.00	-.27333	.83458	.745	-1.9553	1.4087
	4.00	-6.17917*	.83458	.000	-7.8612	-4.4972
4.00	1.00	4.82167*	.83458	.000	3.1397	6.5037
	2.00	5.90583*	.83458	.000	4.2238	7.5878
	3.00	6.17917*	.83458	.000	4.4972	7.8612

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Indian almond, Mango, Avocado pear and adjoining rainforest respectively

Appendix 5.10: Multiple comparisons with LSD test: Calcium concentrations in litterfall

Multiple Comparisons

Dependent Variable: data
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.58167	.75673	.446	-.9434	2.1067
	3.00	-1.27583	.75673	.099	-2.8009	.2492
	4.00	-1.80333*	.75673	.022	-3.3284	-.2783
2.00	1.00	-.58167	.75673	.446	-2.1067	.9434
	3.00	-1.85750*	.75673	.018	-3.3826	-.3324
	4.00	-2.38500*	.75673	.003	-3.9101	-.8599
3.00	1.00	1.27583	.75673	.099	-.2492	2.8009
	2.00	1.85750*	.75673	.018	.3324	3.3826
	4.00	-.52750	.75673	.489	-2.0526	.9976
4.00	1.00	1.80333*	.75673	.022	.2783	3.3284
	2.00	2.38500*	.75673	.003	.8599	3.9101
	3.00	.52750	.75673	.489	-.9976	2.0526

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Indian almond, Mango, Avocado pear and adjoining rainforest respectively

Appendix 5.11: Multiple comparisons with LSD test: Sodium concentrations in litterfall

Multiple Comparisons

Dependent Variable: data
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.07250	.05901	.226	-.0464	.1914
	3.00	-.10000	.05901	.097	-.2189	.0189
	4.00	-.12000*	.05901	.048	-.2389	-.0011
2.00	1.00	-.07250	.05901	.226	-.1914	.0464
	3.00	-.17250*	.05901	.005	-.2914	-.0536
	4.00	-.19250*	.05901	.002	-.3114	-.0736
3.00	1.00	.10000	.05901	.097	-.0189	.2189
	2.00	.17250*	.05901	.005	.0536	.2914
	4.00	-.02000	.05901	.736	-.1389	.0989
4.00	1.00	.12000*	.05901	.048	.0011	.2389
	2.00	.19250*	.05901	.002	.0736	.3114
	3.00	.02000	.05901	.736	-.0989	.1389

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Indian almond, Mango, Avocado pear and adjoining rainforest respectively

Appendix 5.12: Multiple comparisons with LSD test: Magnesium concentrations in litterfall

Multiple Comparisons

Dependent Variable: data
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.62583*	.27501	.028	.0716	1.1801
	3.00	-.86500*	.27501	.003	-1.4192	-.3108
	4.00	-.91500*	.27501	.002	-1.4692	-.3608
2.00	1.00	-.62583*	.27501	.028	-1.1801	-.0716
	3.00	-1.49083*	.27501	.000	-2.0451	-.9366
	4.00	-1.54083*	.27501	.000	-2.0951	-.9866
3.00	1.00	.86500*	.27501	.003	.3108	1.4192
	2.00	1.49083*	.27501	.000	.9366	2.0451
	4.00	-.05000	.27501	.857	-.6042	.5042
4.00	1.00	.91500*	.27501	.002	.3608	1.4692
	2.00	1.54083*	.27501	.000	.9866	2.0951
	3.00	.05000	.27501	.857	-.5042	.6042

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Indian almond, Mango, Avocado pear and adjoining rainforest respectively

Appendix 5.13: ANOVA and Multiple comparisons with LSD test: pH in litterfall

ANOVA

ph

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.908	3	.969	21.671	.000
Within Groups	1.968	44	.045		
Total	4.877	47			

Multiple Comparisons

Dependent Variable: data
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.44167*	.08635	.000	-.6157	-.2676
	3.00	-.55000*	.08635	.000	-.7240	-.3760
	4.00	-.64167*	.08635	.000	-.8157	-.4676
2.00	1.00	.44167*	.08635	.000	.2676	.6157
	3.00	-.10833	.08635	.216	-.2824	.0657
	4.00	-.20000*	.08635	.025	-.3740	-.0260
3.00	1.00	.55000*	.08635	.000	.3760	.7240
	2.00	.10833	.08635	.216	-.0657	.2824
	4.00	-.09167	.08635	.294	-.2657	.0824
4.00	1.00	.64167*	.08635	.000	.4676	.8157
	2.00	.20000*	.08635	.025	.0260	.3740
	3.00	.09167	.08635	.294	-.0824	.2657

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Indian almond, Mango, Avocado pear and adjoining rainforest respectively

Appendix 5.14: Mean Monthly Return of Nitrogen to the Soil Via Litterfall in kg/ha/yr

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	1.20	4.62	1.80	15.47
Mar	2.23	5.92	2.28	23.04
Apr	2.56	5.78	3.23	8.97
May	6.07	3.76	3.10	6.07
Jun	5.48	3.52	3.08	4.32
Jul	7.04	2.98	2.51	3.52
Aug	11.66	2.06	1.94	3.87
Sep	12.05	2.54	2.07	4.03
Oct	15.78	2.68	2.14	4.64
Nov	2.61	2.13	2.09	9.72
Dec	1.21	2.77	2.56	11.54
Jan	0.83	2.96	2.19	13.73
Mean S.D	5.73 5.00	3.48 1.32	2.42 0.48	9.08 6.02

Source: Field work

Appendix 5.15: Mean Monthly Return of Phosphorus to the Soil via Litterfall in kg/ha/yr

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	0.14	0.64	0.50	1.21
Mar	0.25	0.81	0.38	1.28
Apr	0.32	0.57	0.31	0.44
May	0.47	0.42	0.25	0.31
Jun	0.68	0.40	0.24	0.26
Jul	0.94	0.31	0.26	0.22
Aug	1.29	0.36	0.30	0.28
Sep	1.35	0.35	0.34	0.29
Oct	1.83	0.29	0.48	0.40
Nov	0.19	0.29	0.45	0.56
Dec	0.19	0.38	0.75	0.93
Jan	0.12	0.54	0.78	0.99
Mean S.D	0.65 0.58	0.45 0.16	0.42 0.18	0.60 0.39

Source: Field work

Appendix 5.16: Mean Monthly Return of Potassium to the Soil via Litterfall in kg/ha/yr

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	0.65	2.51	1.77	8.12
Mar	1.82	3.58	1.99	6.54
Apr	3.11	4.37	2.50	3.50
May	5.55	3.22	1.09	1.25
Jun	5.18	2.06	0.78	0.90
Jul	6.05	2.05	0.86	0.76
Aug	10.08	2.63	0.96	0.89
Sep	10.32	2.78	1.08	0.95
Oct	13.49	2.15	1.65	1.43
Nov	1.32	2.08	3.06	3.73
Dec	0.85	1.98	4.35	5.72
Jan	0.62	2.29	5.61	6.90
Mean	4.92	2.64	2.14	3.39
S.D	4.37	0.74	1.52	2.76

Source: Field work

Appendix 5.17: Mean Monthly Return of Calcium to the Soil via Litterfall in kg/ha/yr

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	1.49	7.31	5.87	16.18
Mar	2.73	7.90	4.24	14.27
Apr	3.98	6.81	3.96	5.67
May	5.91	4.40	3.55	4.06
Jun	6.74	4.75	3.46	3.88
Jul	10.67	4.48	3.86	3.34
Aug	14.37	4.73	4.25	3.94
Sep	16.19	4.88	4.67	3.92
Oct	21.28	3.70	6.10	5.03
Nov	3.37	3.44	6.65	8.38
Dec	1.96	4.47	8.74	13.01
Jan	1.29	5.76	9.07	12.01
Mean	7.50	5.22	5.37	7.81
S.D	6.63	1.42	1.95	4.76

Source: Field work

Appendix 5.18: Mean Monthly Return of Sodium to the Soil via Litterfall in kg/ha/yr

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	0.08	0.30	0.39	0.99
Mar	0.16	0.34	0.30	1.01
Apr	0.19	0.37	0.21	0.30
May	0.37	0.27	0.16	0.20
Jun	0.38	0.23	0.15	0.18
Jul	0.57	0.24	0.17	0.45
Aug	0.92	0.18	0.20	0.19
Sep	0.91	0.22	0.24	0.20
Oct	1.01	0.16	0.32	0.27
Nov	0.16	0.19	0.41	0.51
Dec	0.09	0.20	0.60	0.75
Jan	0.06	0.25	0.61	0.80
Mean	0.41	0.25	0.31	0.49
S.D	0.36	0.07	0.16	0.32

Source: Field work

Appendix 5.19: Mean Monthly Return of Magnesium to the Soil via Litterfall in kg/ha/yr

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	0.29	1.22	2.14	4.88
Mar	0.59	2.21	1.43	4.82
Apr	1.09	2.28	1.38	2.01
May	2.19	1.30	1.24	1.44
Jun	2.92	1.29	1.15	1.28
Jul	3.00	0.52	1.35	1.13
Aug	4.33	1.07	1.44	1.34
Sep	4.53	0.71	1.69	1.50
Oct	5.81	0.76	2.01	1.64
Nov	0.88	0.71	2.43	2.96
Dec	0.75	0.87	3.08	3.82
Jan	0.28	1.11	3.14	4.01
Mean	2.22	1.17	1.87	2.57
S.D	1.89	0.56	0.70	1.45

Source: Field work

Appendix 5.20: Multiple comparisons with LSD test: Nitrogen returns in litterfall

Multiple Comparisons

Dependent Variable: data
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	2.25000	1.62297	.173	-1.0209	5.5209
	3.00	3.31083*	1.62297	.047	.0399	6.5817
	4.00	-3.35000*	1.62297	.045	-6.6209	-.0791
2.00	1.00	-2.25000	1.62297	.173	-5.5209	1.0209
	3.00	1.06083	1.62297	.517	-2.2101	4.3317
	4.00	-5.60000*	1.62297	.001	-8.8709	-2.3291
3.00	1.00	-3.31083*	1.62297	.047	-6.5817	-.0399
	2.00	-1.06083	1.62297	.517	-4.3317	2.2101
	4.00	-6.66083*	1.62297	.000	-9.9317	-3.3899
4.00	1.00	3.35000*	1.62297	.045	.0791	6.6209
	2.00	5.60000*	1.62297	.001	2.3291	8.8709
	3.00	6.66083*	1.62297	.000	3.3899	9.9317

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Indian almond, Mango, Avocado pear and adjoining rainforest respectively

Appendix 5.21: Multiple comparisons with LSD test: Potassium returns in litterfall

Multiple Comparisons

Dependent Variable: data
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	2.27833*	1.11034	.046	.0406	4.5161
	3.00	2.77833*	1.11034	.016	.5406	5.0161
	4.00	1.52917	1.11034	.175	-.7086	3.7669
2.00	1.00	-2.27833*	1.11034	.046	-4.5161	-.0406
	3.00	.50000	1.11034	.655	-1.7377	2.7377
	4.00	-.74917	1.11034	.503	-2.9869	1.4886
3.00	1.00	-2.77833*	1.11034	.016	-5.0161	-.5406
	2.00	-.50000	1.11034	.655	-2.7377	1.7377
	4.00	-1.24917	1.11034	.267	-3.4869	.9886
4.00	1.00	-1.52917	1.11034	.175	-3.7669	.7086
	2.00	.74917	1.11034	.503	-1.4886	2.9869
	3.00	1.24917	1.11034	.267	-.9886	3.4869

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Indian almond, Mango, Avocado pear and adjoining rainforest respectively

Appendix 5.22: Multiple comparisons with LSD test: Sodium returns in litterfall

Multiple Comparisons

Dependent Variable: data
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.16250	.10410	.126	-.0473	.3723
	3.00	.09500	.10410	.366	-.1148	.3048
	4.00	-.07917	.10410	.451	-.2890	.1306
2.00	1.00	-.16250	.10410	.126	-.3723	.0473
	3.00	-.06750	.10410	.520	-.2773	.1423
	4.00	-.24167*	.10410	.025	-.4515	-.0319
3.00	1.00	-.09500	.10410	.366	-.3048	.1148
	2.00	.06750	.10410	.520	-.1423	.2773
	4.00	-.17417	.10410	.101	-.3840	.0356
4.00	1.00	.07917	.10410	.451	-.1306	.2890
	2.00	.24167*	.10410	.025	.0319	.4515
	3.00	.17417	.10410	.101	-.0356	.3840

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Indian almond, Mango, Avocado pear and adjoining rainforest respectively

Appendix 5.23: Multiple comparisons with LSD test: Magnesium returns in litterfall

Multiple Comparisons

Dependent Variable: data
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	1.05083*	.51851	.049	.0058	2.0958
	3.00	.34833	.51851	.505	-.6967	1.3933
	4.00	-.34750	.51851	.506	-1.3925	.6975
2.00	1.00	-1.05083*	.51851	.049	-2.0958	-.0058
	3.00	-.70250	.51851	.182	-1.7475	.3425
	4.00	-1.39833*	.51851	.010	-2.4433	-.3533
3.00	1.00	-.34833	.51851	.505	-1.3933	.6967
	2.00	.70250	.51851	.182	-.3425	1.7475
	4.00	-.69583	.51851	.186	-1.7408	.3492
4.00	1.00	.34750	.51851	.506	-.6975	1.3925
	2.00	1.39833*	.51851	.010	.3533	2.4433
	3.00	.69583	.51851	.186	-.3492	1.7408

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Indian almond, Mango, Avocado pear and adjoining rainforest respectively

Appendix 5.24: Mean Concentrations of Nitrogen in Throughfall in mg l◌^{1}

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest	Incident Rainfall
Feb	7.76	7.08	7.16	8.51	0.23
Mar	7.74	7.04	7.14	8.44	0.24
Apr	7.06	6.66	6.56	8.06	0.26
May	5.60	5.90	5.60	6.20	0.20
Jun	5.38	4.98	4.38	5.58	0.18
Jul	4.04	3.84	3.64	4.94	0.14
Aug	5.81	5.11	4.31	7.01	0.21
Sep	3.96	3.66	3.16	4.86	0.16
Oct	4.87	4.37	3.97	5.17	0.17
Nov	5.29	4.99	4.39	5.79	0.19
Dec	6.62	6.92	6.92	7.42	0.22
Jan	7.81	7.06	7.02	7.64	0.25
Mean	5.99	5.63	5.35	6.64	0.20
S.D	1.39	1.30	1.53	1.37	0.04

Source: Field work

Appendix 5.25: Mean Concentrations of Phosphorus in Throughfall in mg l◌^{1}

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest	Incident Rainfall
Feb	7.46	7.66	6.98	6.89	0.20
Mar	7.41	7.61	6.91	6.81	0.21
Apr	5.99	6.79	5.39	5.19	0.19
May	4.76	5.36	4.46	4.96	0.16
Jun	3.52	3.62	3.22	3.32	0.12
Jul	3.01	3.11	2.51	2.81	0.11
Aug	3.07	3.47	2.97	3.07	0.17
Sep	2.70	3.03	2.60	2.90	0.10
Oct	3.31	4.31	3.01	3.01	0.11
Nov	4.93	5.13	3.23	3.43	0.13
Dec	7.08	7.28	5.38	5.28	0.18
Jan	7.45	7.64	6.04	5.30	0.18
Mean	5.06	5.42	4.39	4.41	0.16
S.D	1.94	1.89	1.68	1.51	0.04

Source: Field work

Appendix 5.26: Mean Concentrations of Potassium in Throughfall in mg l^{-1}

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest	Incident Rainfall
Feb	87.4	81.5	57.8	89.6	2.8
Mar	87.3	81.2	57.6	89.4	3.0
Apr	82.5	63.1	53.1	85.4	2.8
May	54.9	46.1	45.5	60.6	2.6
Jun	47.6	38.3	26.3	52.4	2.0
Jul	40.5	32.0	24.3	41.7	1.9
Aug	49.9	39.0	27.0	56.8	2.2
Sep	37.5	30.7	23.0	34.5	1.8
Oct	42.3	31.4	23.6	49.7	1.8
Nov	49.0	40.0	29.3	54.3	2.6
Dec	84.0	68.2	56.9	81.3	2.8
Jan	87.2	81.7	57.4	89.0	2.9
Mean	62.51	52.77	40.15	65.39	2.43
S.D	20.99	20.88	15.64	20.28	0.46

Source: Field work

Appendix 5.27: Mean Concentrations of Calcium in Throughfall in mg l^{-1}

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest	Incident Rainfall
Feb	45.8	39.2	35.9	45.8	2.5
Mar	46.1	39.1	35.8	45.2	2.4
Apr	42.4	35.8	30.5	41.0	1.9
May	40.4	28.0	23.8	32.0	1.8
Jun	16.2	18.8	18.2	22.5	2.0
Jul	14.9	16.7	16.3	18.5	1.8
Aug	16.9	17.6	16.9	24.6	2.2
Sep	12.7	16.5	10.8	16.6	1.9
Oct	21.5	20.5	13.1	21.9	1.9
Nov	23.4	24.2	14.5	22.8	2.0
Dec	41.0	38.6	35.1	40.9	2.2
Jan	45.6	39.0	35.6	43.4	2.5
Mean	30.58	27.83	23.88	31.27	2.09
S.D	13.94	9.84	10.03	11.28	0.26

Source: Field work

Appendix 5.28: Mean Concentrations of Sodium in Throughfall in mg l^{-1}

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest	Incident Rainfall
Feb	1.16	1.28	1.20	1.19	0.11
Mar	1.09	1.00	1.10	1.05	0.08
Apr	0.99	0.96	1.04	0.94	0.10
May	0.79	0.81	1.07	0.76	0.09
Jun	0.71	0.84	0.85	0.69	0.06
Jul	0.65	0.72	0.76	0.62	0.08
Aug	0.57	0.85	0.68	0.56	0.04
Sep	0.62	0.80	0.69	0.77	0.06
Oct	0.77	0.88	1.03	0.84	0.09
Nov	1.07	1.05	1.09	0.95	0.07
Dec	1.11	1.21	1.16	1.18	0.10
Jan	1.15	1.31	1.20	1.19	0.11
Mean	0.89	0.98	0.99	0.90	0.08
S.D	0.23	0.20	0.19	0.22	0.02

Source: Field work

Appendix 5.29: Mean Concentrations of Magnesium in Throughfall in mg l^{-1}

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest	Incident Rainfall
Feb	31.2	28.6	28.2	30.2	2.7
Mar	31.2	28.2	27.6	29.1	2.8
Apr	29.1	25.7	26.6	27.2	2.4
May	24.3	25.0	25.4	24.1	2.0
Jun	13.4	17.9	21.0	10.6	1.8
Jul	11.6	11.8	11.2	10.0	1.6
Aug	15.4	17.5	14.5	12.5	1.8
Sep	10.5	12.0	11.7	9.4	1.4
Oct	12.7	14.2	15.3	11.8	1.9
Nov	15.5	18.3	25.3	12.4	2.1
Dec	30.7	27.3	27.2	28.1	2.7
Jan	31.8	29.0	28.4	30.2	2.7
Mean	21.45	21.29	21.87	19.63	2.16
S.D	8.94	6.68	6.78	9.07	0.49

Source: Field work

Appendix 5.30: Monthly pH values in Throughfall

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest	Incident Rainfall
Feb	5.6	5.7	5.8	5.1	6.0
Mar	5.0	5.5	5.2	5.0	5.9
Apr	4.9	5.4	5.7	5.1	6.1
May	5.0	5.6	5.4	5.5	6.0
Jun	5.3	5.6	6.0	5.4	6.2
Jul	5.4	5.6	6.0	5.5	6.2
Aug	4.7	6.0	5.7	5.7	6.1
Sep	5.6	5.8	6.0	5.8	6.2
Oct	5.1	5.6	6.0	5.6	6.3
Nov	5.8	5.4	5.6	5.4	5.9
Dec	5.1	5.5	5.7	5.0	6.2
Jan	5.4	5.6	5.7	5.0	6.0
Mean	5.24	5.61	5.73	5.34	6.09
S.D	0.33	0.17	0.25	0.29	0.13

Source: Field work

Appendix 5.31: Multiple comparisons with LSD test: Nitrogen concentrations in throughfall

Multiple Comparisons

Dependent Variable: stands
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	2.00	.36083	.51223	.484	-.6657	1.3874
	3.00	.64083	.51223	.216	-.3857	1.6674
	4.00	-.64000	.51223	.217	-1.6665	.3865
	5.00	5.79083*	.51223	.000	4.7643	6.8174
2.00	1.00	-.36083	.51223	.484	-1.3874	.6657
	3.00	.28000	.51223	.587	-.7465	1.3065
	4.00	-1.00083	.51223	.056	-2.0274	.0257
	5.00	5.43000*	.51223	.000	4.4035	6.4565
3.00	1.00	-.64083	.51223	.216	-1.6674	.3857
	2.00	-.28000	.51223	.587	-1.3065	.7465
	4.00	-1.28083*	.51223	.015	-2.3074	-.2543
	5.00	5.15000*	.51223	.000	4.1235	6.1765
4.00	1.00	.64000	.51223	.217	-.3865	1.6665
	2.00	1.00083	.51223	.056	-.0257	2.0274
	3.00	1.28083*	.51223	.015	.2543	2.3074
	5.00	6.43083*	.51223	.000	5.4043	7.4574
5.00	1.00	-5.79083*	.51223	.000	-6.8174	-4.7643
	2.00	-5.43000*	.51223	.000	-6.4565	-4.4035
	3.00	-5.15000*	.51223	.000	-6.1765	-4.1235
	4.00	-6.43083*	.51223	.000	-7.4574	-5.4043

*. The mean difference is significant at the .05 level.

1, 2, 3, 4, 5, represent Indian almond, Mango, Avocado pear, adjoining rainforest and incident rainfall respectively

Appendix 5.32: Multiple comparisons with LSD : Phosphorus concentrations in throughfall

Multiple Comparisons

Dependent Variable: stands
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.36000	.64426	.579	-1.6511	.9311
	3.00	.66583	.64426	.306	-.6253	1.9570
	4.00	.64333	.64426	.322	-.6478	1.9345
	5.00	4.90250*	.64426	.000	3.6114	6.1936
2.00	1.00	.36000	.64426	.579	-.9311	1.6511
	3.00	1.02583	.64426	.117	-.2653	2.3170
	4.00	1.00333	.64426	.125	-.2878	2.2945
	5.00	5.26250*	.64426	.000	3.9714	6.5536
3.00	1.00	-.66583	.64426	.306	-1.9570	.6253
	2.00	-1.02583	.64426	.117	-2.3170	.2653
	4.00	-.02250	.64426	.972	-1.3136	1.2686
	5.00	4.23667*	.64426	.000	2.9455	5.5278
4.00	1.00	-.64333	.64426	.322	-1.9345	.6478
	2.00	-1.00333	.64426	.125	-2.2945	.2878
	3.00	.02250	.64426	.972	-1.2686	1.3136
	5.00	4.25917*	.64426	.000	2.9680	5.5503
5.00	1.00	-4.90250*	.64426	.000	-6.1936	-3.6114
	2.00	-5.26250*	.64426	.000	-6.5536	-3.9714
	3.00	-4.23667*	.64426	.000	-5.5278	-2.9455
	4.00	-4.25917*	.64426	.000	-5.5503	-2.9680

*. The mean difference is significant at the .05 level.

1, 2, 3, 4, 5, represent Indian almond, Mango, Avocado pear, adjoining rainforest and incident rainfall respectively

Appendix 5.33: Multiple comparisons with LSD: Potassium concentrations in throughfall

Multiple Comparisons

Dependent Variable: stands
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	9.74167	7.14789	.178	-4.5830	24.0664
	3.00	22.35833*	7.14789	.003	8.0336	36.6830
	4.00	-2.88333	7.14789	.688	-17.2080	11.4414
	5.00	60.07500*	7.14789	.000	45.7503	74.3997
2.00	1.00	-9.74167	7.14789	.178	-24.0664	4.5830
	3.00	12.61667	7.14789	.083	-1.7080	26.9414
	4.00	-12.62500	7.14789	.083	-26.9497	1.6997
	5.00	50.33333*	7.14789	.000	36.0086	64.6580
3.00	1.00	-22.35833*	7.14789	.003	-36.6830	-8.0336
	2.00	-12.61667	7.14789	.083	-26.9414	1.7080
	4.00	-25.24167*	7.14789	.001	-39.5664	-10.9170
	5.00	37.71667*	7.14789	.000	23.3920	52.0414
4.00	1.00	2.88333	7.14789	.688	-11.4414	17.2080
	2.00	12.62500	7.14789	.083	-1.6997	26.9497
	3.00	25.24167*	7.14789	.001	10.9170	39.5664
	5.00	62.95833*	7.14789	.000	48.6336	77.2830
5.00	1.00	-60.07500*	7.14789	.000	-74.3997	-45.7503
	2.00	-50.33333*	7.14789	.000	-64.6580	-36.0086
	3.00	-37.71667*	7.14789	.000	-52.0414	-23.3920
	4.00	-62.95833*	7.14789	.000	-77.2830	-48.6336

*. The mean difference is significant at the .05 level.

1, 2, 3, 4, 5, represent Indian almond, Mango, Avocado pear, adjoining rainforest and incident rainfall respectively

Appendix 5.34: Multiple comparisons with LSD test: Calcium concentrations in throughfall

Multiple Comparisons

Dependent Variable: stands
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	2.74167	4.15964	.513	-5.5944	11.0778
	3.00	6.70000	4.15964	.113	-1.6361	15.0361
	4.00	-.69167	4.15964	.869	-9.0278	7.6444
	5.00	28.48333*	4.15964	.000	20.1472	36.8194
2.00	1.00	-2.74167	4.15964	.513	-11.0778	5.5944
	3.00	3.95833	4.15964	.345	-4.3778	12.2944
	4.00	-3.43333	4.15964	.413	-11.7694	4.9028
	5.00	25.74167*	4.15964	.000	17.4056	34.0778
3.00	1.00	-6.70000	4.15964	.113	-15.0361	1.6361
	2.00	-3.95833	4.15964	.345	-12.2944	4.3778
	4.00	-7.39167	4.15964	.081	-15.7278	.9444
	5.00	21.78333*	4.15964	.000	13.4472	30.1194
4.00	1.00	.69167	4.15964	.869	-7.6444	9.0278
	2.00	3.43333	4.15964	.413	-4.9028	11.7694
	3.00	7.39167	4.15964	.081	-.9444	15.7278
	5.00	29.17500*	4.15964	.000	20.8389	37.5111
5.00	1.00	-28.48333*	4.15964	.000	-36.8194	-20.1472
	2.00	-25.74167*	4.15964	.000	-34.0778	-17.4056
	3.00	-21.78333*	4.15964	.000	-30.1194	-13.4472
	4.00	-29.17500*	4.15964	.000	-37.5111	-20.8389

*. The mean difference is significant at the .05 level.

1, 2, 3, 4, 5, represent Indian almond, Mango, Avocado pear, adjoining rainforest and incident rainfall respectively

Appendix 5.35: Multiple comparisons with LSD test: Sodium concentrations in throughfall

Multiple Comparisons

Dependent Variable: stands
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.08583	.07703	.270	-.2402	.0685
	3.00	-.09917	.07703	.203	-.2535	.0552
	4.00	-.00500	.07703	.948	-.1594	.1494
	5.00	.80750*	.07703	.000	.6531	.9619
2.00	1.00	.08583	.07703	.270	-.0685	.2402
	3.00	-.01333	.07703	.863	-.1677	.1410
	4.00	.08083	.07703	.299	-.0735	.2352
	5.00	.89333*	.07703	.000	.7390	1.0477
3.00	1.00	.09917	.07703	.203	-.0552	.2535
	2.00	.01333	.07703	.863	-.1410	.1677
	4.00	.09417	.07703	.227	-.0602	.2485
	5.00	.90667*	.07703	.000	.7523	1.0610
4.00	1.00	.00500	.07703	.948	-.1494	.1594
	2.00	-.08083	.07703	.299	-.2352	.0735
	3.00	-.09417	.07703	.227	-.2485	.0602
	5.00	.81250*	.07703	.000	.6581	.9669
5.00	1.00	-.80750*	.07703	.000	-.9619	-.6531
	2.00	-.89333*	.07703	.000	-1.0477	-.7390
	3.00	-.90667*	.07703	.000	-1.0610	-.7523
	4.00	-.81250*	.07703	.000	-.9669	-.6581

*. The mean difference is significant at the .05 level.

1, 2, 3, 4, 5, represent Indian almond, Mango, Avocado pear, adjoining rainforest and incident rainfall respectively

Appendix 5.36: Multiple comparisons using the LSD: Magnesium concentrations in throughfall:

Multiple Comparisons

Dependent Variable: stands
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.15833	2.90522	.957	-5.6639	5.9805
	3.00	-.41667	2.90522	.886	-6.2389	5.4055
	4.00	1.81667	2.90522	.534	-4.0055	7.6389
	5.00	19.29167*	2.90522	.000	13.4695	25.1139
2.00	1.00	-.15833	2.90522	.957	-5.9805	5.6639
	3.00	-.57500	2.90522	.844	-6.3972	5.2472
	4.00	1.65833	2.90522	.570	-4.1639	7.4805
	5.00	19.13333*	2.90522	.000	13.3111	24.9555
3.00	1.00	.41667	2.90522	.886	-5.4055	6.2389
	2.00	.57500	2.90522	.844	-5.2472	6.3972
	4.00	2.23333	2.90522	.445	-3.5889	8.0555
	5.00	19.70833*	2.90522	.000	13.8861	25.5305
4.00	1.00	-1.81667	2.90522	.534	-7.6389	4.0055
	2.00	-1.65833	2.90522	.570	-7.4805	4.1639
	3.00	-2.23333	2.90522	.445	-8.0555	3.5889
	5.00	17.47500*	2.90522	.000	11.6528	23.2972
5.00	1.00	-19.29167*	2.90522	.000	-25.1139	-13.4695
	2.00	-19.13333*	2.90522	.000	-24.9555	-13.3111
	3.00	-19.70833*	2.90522	.000	-25.5305	-13.8861
	4.00	-17.47500*	2.90522	.000	-23.2972	-11.6528

*. The mean difference is significant at the .05 level.

1, 2, 3, 4, 5, represent Indian almond, Mango, Avocado pear, adjoining rainforest and incident rainfall respectively

Appendix 5.37: ANOVA and Multiple comparisons with LSD test: pH values in throughfall

ANOVA

phtf

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.456	4	1.364	22.574	.000
Within Groups	3.323	55	.060		
Total	8.779	59			

Multiple Comparisons

Dependent Variable: stands
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.36667*	.10035	.001	-.5678	-.1656
	3.00	-.49167*	.10035	.000	-.6928	-.2906
	4.00	-.10000	.10035	.323	-.3011	.1011
	5.00	-.85000*	.10035	.000	-1.0511	-.6489
2.00	1.00	.36667*	.10035	.001	.1656	.5678
	3.00	-.12500	.10035	.218	-.3261	.0761
	4.00	.26667*	.10035	.010	.0656	.4678
	5.00	-.48333*	.10035	.000	-.6844	-.2822
3.00	1.00	.49167*	.10035	.000	.2906	.6928
	2.00	.12500	.10035	.218	-.0761	.3261
	4.00	.39167*	.10035	.000	.1906	.5928
	5.00	-.35833*	.10035	.001	-.5594	-.1572
4.00	1.00	.10000	.10035	.323	-.1011	.3011
	2.00	-.26667*	.10035	.010	-.4678	-.0656
	3.00	-.39167*	.10035	.000	-.5928	-.1906
	5.00	-.75000*	.10035	.000	-.9511	-.5489
5.00	1.00	.85000*	.10035	.000	.6489	1.0511
	2.00	.48333*	.10035	.000	.2822	.6844
	3.00	.35833*	.10035	.001	.1572	.5594
	4.00	.75000*	.10035	.000	.5489	.9511

*. The mean difference is significant at the .05 level.

1, 2, 3, 4, 5, represent Indian almond, Mango, Avocado pear, adjoining rainforest and incident rainfall respectively

Appendix 5.38: Mean Monthly Return of Nitrogen to the Soil via Throughfall in kg/ha

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	6.6	4.8	3.0	7.4
Mar	6.6	4.7	2.8	7.1
Apr	5.7	4.7	2.6	6.8
May	4.5	3.6	2.2	6.0
Jun	4.4	2.8	1.7	5.6
Jul	2.7	2.2	1.4	4.8
Aug	4.6	2.9	1.6	6.1
Sep	2.6	2.1	1.3	4.4
Oct	3.8	2.6	1.8	5.0
Nov	4.4	2.8	2.0	5.3
Dec	5.6	3.8	2.8	6.7
Jan	6.8	4.7	3.1	7.3
Mean	**4.86**	**3.47**	**2.19**	**6.04**
S.D	**1.43**	**1.04**	**0.65**	**1.03**

Source: Field work

Appendix 5.39: Mean Monthly Return of Phosphorus to the Soil via Throughfall in kg/ha

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	1.3	1.4	0.5	1.0
Mar	1.0	1.0	0.5	0.8
Apr	0.8	0.8	0.4	0.5
May	0.7	0.6	0.3	0.4
Jun	0.6	0.6	0.2	0.4
Jul	0.6	0.3	0.1	0.2
Aug	0.3	0.5	0.2	0.3
Sep	0.4	0.3	0.1	0.2
Oct	0.2	0.6	0.2	0.3
Nov	0.5	0.6	0.3	0.4
Dec	0.7	1.2	0.4	0.8
Jan	0.9	1.4	0.6	1.1
Mean	**0.66**	**0.78**	**0.32**	**0.53**
S.D	**0.31**	**0.39**	**0.16**	**0.31**

Source: Field work

Appendix 5.40: Mean Monthly Return of Potassium to the Soil via Throughfall in kg/ha

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	14.2	11.8	11.7	13.6
Mar	12.6	11.0	9.4	12.2
Apr	12.1	10.4	7.6	10.2
May	10.8	9.0	6.7	8.4
Jun	7.3	9.0	5.8	6.0
Jul	6.8	6.5	4.4	4.4
Aug	8.6	8.3	5.8	5.2
Sep	7.2	6.3	4.4	4.3
Oct	9.6	9.2	4.6	7.2
Nov	10.2	10.0	6.8	8.4
Dec	12.9	10.7	9.6	11.0
Jan	14.3	11.4	11.6	14.2
Mean	**10.55**	**9.47**	**7.37**	**8.76**
S.D	**2.70**	**1.78**	**2.64**	**3.49**

Source: Field work

Appendix 5.41: Mean Monthly Return of Calcium to the Soil via Throughfall in kg/ha

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	11.6	10.4	7.4	8.0
Mar	8.1	8.6	6.8	6.5
Apr	6.2	5.0	4.3	5.3
May	5.8	3.6	2.0	3.0
Jun	4.8	3.3	2.0	2.8
Jul	3.2	2.8	1.8	1.8
Aug	5.6	3.7	2.8	2.6
Sep	3.0	3.0	1.6	1.9
Oct	5.7	3.8	2.2	2.8
Nov	7.8	5.2	3.8	3.6
Dec	8.7	9.2	6.4	7.2
Jan	11.6	10.6	7.8	8.1
Mean	**6.84**	**5.77**	**4.08**	**4.47**
S.D	**2.83**	**3.03**	**2.39**	**2.41**

Source: Field work

Appendix 5.42: Mean Monthly Return of Sodium to the Soil via Throughfall in kg/ha

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	1.02	1.30	1.30	1.21
Mar	0.61	1.18	1.20	1.06
Apr	0.40	1.06	1.10	0.81
May	0.24	0.62	0.87	0.45
Jun	0.13	0.47	0.56	0.28
Jul	0.13	0.28	0.24	0.15
Aug	0.16	0.43	0.48	0.30
Sep	0.12	0.28	0.22	0.14
Oct	0.26	0.64	0.58	0.36
Nov	0.62	0.91	1.08	0.84
Dec	0.81	1.20	1.24	1.01
Jan	1.02	1.30	1.36	1.18
Mean	**0.46**	**0.81**	**0.85**	**0.65**
S.D	**0.35**	**0.40**	**0.42**	**0.41**

Source: Field work

Appendix 5.43: Mean Monthly Return of Magnesium to the Soil via Throughfall in kg/ha

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	8.49	4.12	8.63	4.02
Mar	5.82	2.18	6.62	2.27
Apr	3.74	2.06	4.85	2.06
May	2.16	2.00	2.86	1.95
Jun	2.10	1.97	2.86	1.95
Jul	1.15	0.93	1.51	0.81
Aug	3.08	1.02	2.84	1.64
Sep	1.06	0.92	1.50	0.83
Oct	2.18	1.28	2.36	1.67
Nov	3.90	2.08	5.47	2.12
Dec	7.37	3.24	7.58	2.16
Jan	8.87	4.27	8.71	4.11
Mean	**4.16**	**2.17**	**4.65**	**2.13**
S.D	**2.80**	**1.16**	**2.70**	**1.02**

Source: Field work

Appendix 5.44: Multiple comparisons with LSD test: Nitrogen returns in throughfall

Multiple Comparisons

Dependent Variable: Nreturns
LSD

(I) sites	(J) sites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	1.38333*	.43827	.003	.5001	2.2666
	3.00	2.66667*	.43827	.000	1.7834	3.5499
	4.00	-1.18333*	.43827	.010	-2.0666	-.3001
2.00	1.00	-1.38333*	.43827	.003	-2.2666	-.5001
	3.00	1.28333*	.43827	.005	.4001	2.1666
	4.00	-2.56667*	.43827	.000	-3.4499	-1.6834
3.00	1.00	-2.66667*	.43827	.000	-3.5499	-1.7834
	2.00	-1.28333*	.43827	.005	-2.1666	-.4001
	4.00	-3.85000*	.43827	.000	-4.7333	-2.9667
4.00	1.00	1.18333*	.43827	.010	.3001	2.0666
	2.00	2.56667*	.43827	.000	1.6834	3.4499
	3.00	3.85000*	.43827	.000	2.9667	4.7333

*. The mean difference is significant at the .05 level.

1, 2,3 and 4 represent Indian almond, Mango, Avocado pear, and Adjoining rainforest respectively

Appendix 5.45: Multiple comparisons with LSD test: Phosphorus returns in throughfall

Multiple Comparisons

Dependent Variable: Preturns
LSD

(I) sites	(J) sites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.10833	.12420	.388	-.3586	.1420
	3.00	.35000*	.12420	.007	.0997	.6003
	4.00	.13333	.12420	.289	-.1170	.3836
2.00	1.00	.10833	.12420	.388	-.1420	.3586
	3.00	.45833*	.12420	.001	.2080	.7086
	4.00	.24167	.12420	.058	-.0086	.4920
3.00	1.00	-.35000*	.12420	.007	-.6003	-.0997
	2.00	-.45833*	.12420	.001	-.7086	-.2080
	4.00	-.21667	.12420	.088	-.4670	.0336
4.00	1.00	-.13333	.12420	.289	-.3836	.1170
	2.00	-.24167	.12420	.058	-.4920	.0086
	3.00	.21667	.12420	.088	-.0336	.4670

*. The mean difference is significant at the .05 level.

1, 2,3 and 4 represent Indian almond, Mango, Avocado pear, and Adjoining rainforest respectively

Appendix 5.46: Multiple comparisons with LSD test: Potassium returns in throughfall

Multiple Comparisons

Dependent Variable: Kreturns
LSD

(I) sites	(J) sites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	1.08333	1.11088	.335	-1.1555	3.3222
	3.00	3.18333*	1.11088	.006	.9445	5.4222
	4.00	1.79167	1.11088	.114	-.4472	4.0305
2.00	1.00	-1.08333	1.11088	.335	-3.3222	1.1555
	3.00	2.10000	1.11088	.065	-.1388	4.3388
	4.00	.70833	1.11088	.527	-1.5305	2.9472
3.00	1.00	-3.18333*	1.11088	.006	-5.4222	-.9445
	2.00	-2.10000	1.11088	.065	-4.3388	.1388
	4.00	-1.39167	1.11088	.217	-3.6305	.8472
4.00	1.00	-1.79167	1.11088	.114	-4.0305	.4472
	2.00	-.70833	1.11088	.527	-2.9472	1.5305
	3.00	1.39167	1.11088	.217	-.8472	3.6305

*. The mean difference is significant at the .05 level.

1, 2,3 and 4 represent Indian almond, Mango, Avocado pear, and Adjoining rainforest respectively

Appendix 5.47: Multiple comparisons with LSD test: Calcium returns in throughfall

Multiple Comparisons

Dependent Variable: Careturns
LSD

(I) sites	(J) sites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	1.07500	1.09279	.331	-1.1274	3.2774
	3.00	2.76667*	1.09279	.015	.5643	4.9690
	4.00	2.37500*	1.09279	.035	.1726	4.5774
2.00	1.00	-1.07500	1.09279	.331	-3.2774	1.1274
	3.00	1.69167	1.09279	.129	-.5107	3.8940
	4.00	1.30000	1.09279	.241	-.9024	3.5024
3.00	1.00	-2.76667*	1.09279	.015	-4.9690	-.5643
	2.00	-1.69167	1.09279	.129	-3.8940	.5107
	4.00	-.39167	1.09279	.722	-2.5940	1.8107
4.00	1.00	-2.37500*	1.09279	.035	-4.5774	-.1726
	2.00	-1.30000	1.09279	.241	-3.5024	.9024
	3.00	.39167	1.09279	.722	-1.8107	2.5940

*. The mean difference is significant at the .05 level.

1, 2,3 and 4 represent Indian almond, Mango, Avocado pear, and Adjoining rainforest respectively

Appendix 5.48: Multiple comparisons with LSD test: Sodium returns in throughfall

Multiple Comparisons

Dependent Variable: Nareturns
LSD

(I) sites	(J) sites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.34583*	.16055	.037	-.6694	-.0223
	3.00	-.39250*	.16055	.019	-.7161	-.0689
	4.00	-.18917	.16055	.245	-.5127	.1344
2.00	1.00	.34583*	.16055	.037	.0223	.6694
	3.00	-.04667	.16055	.773	-.3702	.2769
	4.00	.15667	.16055	.334	-.1669	.4802
3.00	1.00	.39250*	.16055	.019	.0689	.7161
	2.00	.04667	.16055	.773	-.2769	.3702
	4.00	.20333	.16055	.212	-.1202	.5269
4.00	1.00	.18917	.16055	.245	-.1344	.5127
	2.00	-.15667	.16055	.334	-.4802	.1669
	3.00	-.20333	.16055	.212	-.5269	.1202

*. The mean difference is significant at the .05 level.

1, 2,3 and 4 represent Indian almond, Mango, Avocado pear, and Adjoining rainforest respectively

Appendix 5.49: Multiple comparisons with LSD test: Magnesium returns in throughfall

Multiple Comparisons

Dependent Variable: Mgreturns
LSD

(I) sites	(J) sites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	1.98750*	.85409	.025	.2662	3.7088
	3.00	-.48917	.85409	.570	-2.2105	1.2321
	4.00	2.02750*	.85409	.022	.3062	3.7488
2.00	1.00	-1.98750*	.85409	.025	-3.7088	-.2662
	3.00	-2.47667*	.85409	.006	-4.1980	-.7554
	4.00	.04000	.85409	.963	-1.6813	1.7613
3.00	1.00	.48917	.85409	.570	-1.2321	2.2105
	2.00	2.47667*	.85409	.006	.7554	4.1980
	4.00	2.51667*	.85409	.005	.7954	4.2380
4.00	1.00	-2.02750*	.85409	.022	-3.7488	-.3062
	2.00	-.04000	.85409	.963	-1.7613	1.6813
	3.00	-2.51667*	.85409	.005	-4.2380	-.7954

*. The mean difference is significant at the .05 level.

1, 2,3 and 4 represent Indian almond, Mango, Avocado pear, and Adjoining rainforest respectively

Appendix 5.50: Mean Concentrations of Nitrogen in Stemflow in mg l^{-1}

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest	Incident Rainfall
Feb	0.55	0.35	0.53	0.55	0.23
Mar	0.54	0.34	0.52	0.54	0.24
Apr	0.66	0.46	0.56	0.66	0.26
May	0.60	0.40	0.50	0.70	0.20
Jun	0.68	0.50	0.58	0.78	0.18
Jul	0.84	0.55	0.74	0.94	0.14
Aug	0.71	0.55	0.61	0.81	0.21
Sep	0.86	0.59	0.66	0.96	0.16
Oct	0.67	0.40	0.57	0.87	0.17
Nov	0.59	0.41	0.49	0.59	0.19
Dec	0.52	0.34	0.42	0.52	0.22
Jan	0.55	0.33	0.46	0.55	0.25
Mean	**0.65**	**0.44**	**0.55**	**0.71**	**0.20**
S.D	**0.11**	**0.09**	**0.09**	**0.16**	**0.04**

Source: Field work

Appendix 5.51: Mean Concentrations of Phosphorus in Stemflow in mg l^{-1}

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest	Incident Rainfall
Feb	0.47	0.54	0.34	0.46	0.20
Mar	0.41	0.55	0.31	0.51	0.21
Apr	0.39	0.51	0.39	0.49	0.19
May	0.56	0.60	0.36	0.56	0.16
Jun	0.72	0.72	0.52	0.62	0.12
Jul	0.71	0.83	0.51	0.71	0.11
Aug	0.57	0.80	0.47	0.67	0.17
Sep	0.70	0.82	0.50	0.70	0.10
Oct	0.51	0.62	0.41	0.61	0.11
Nov	0.53	0.57	0.33	0.43	0.13
Dec	0.48	0.52	0.28	0.38	0.18
Jan	0.46	0.52	0.31	0.39	0.18
Mean	**0.54**	**0.63**	**0.39**	**0.54**	**0.16**
S.D	**0.11**	**0.13**	**0.09**	**0.12**	**0.04**

Source: Field work

Appendix 5.52: Mean Concentrations of Potassium in Stemflow in mg l^{-1}

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest	Incident Rainfall
Feb	11.2	10.1	10.7	11.2	2.8
Mar	12.2	10.7	11.4	11.4	3.0
Apr	10.2	10.3	10.8	10.0	2.8
May	11.5	9.9	10.8	11.2	2.6
Jun	12.9	11.4	11.6	10.8	2.0
Jul	15.2	10.8	12.1	12.0	1.9
Aug	14.9	11.9	12.0	15.4	2.2
Sep	14.8	9.1	12.5	15.4	1.8
Oct	12.6	9.8	11.1	14.0	1.8
Nov	10.2	10.0	11.3	11.4	2.6
Dec	11.3	10.0	10.3	11.4	2.8
Jan	11.0	10.3	11.1	11.2	2.9
Mean	**12.33**	**10.36**	**11.31**	**12.12**	**2.43**
S.D	**1.79**	**0.75**	**0.65**	**1.79**	**0.46**

Source: Field work

Appendix 5.52: Mean Concentrations of Calcium in Stemflow in mg l^{-1}

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest	Incident Rainfall
Feb	6.1	5.0	5.6	5.3	2.5
Mar	6.2	5.2	5.5	5.6	2.4
Apr	5.1	4.3	4.8	4.7	1.9
May	4.6	3.9	4.6	4.5	1.8
Jun	5.9	4.9	5.9	5.8	2.0
Jul	7.5	6.5	7.6	7.4	1.8
Aug	7.2	6.4	7.6	6.7	2.2
Sep	7.9	6.9	7.9	7.7	1.9
Oct	6.8	5.3	6.9	6.7	1.9
Nov	5.9	5.0	6.1	5.6	2.0
Dec	5.4	5.8	5.8	4.6	2.2
Jan	6.0	5.8	5.8	5.0	2.5
Mean	**6.22**	**5.42**	**6.18**	**5.80**	**2.09**
S.D	**0.98**	**0.90**	**1.09**	**1.09**	**0.26**

Source: Field work

Appendix 5.54: Mean Concentrations of Sodium in Stemflow in mg l^{-1}

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest	Incident Rainfall
Feb	0.31	0.30	0.34	0.36	0.11
Mar	0.31	0.30	0.34	0.34	0.08
Apr	0.38	0.34	0.38	0.41	0.10
May	0.43	0.45	0.37	0.55	0.09
Jun	0.38	0.44	0.38	0.46	0.06
Jul	0.54	0.50	0.44	0.56	0.08
Aug	0.52	0.47	0.61	0.49	0.04
Sep	0.58	0.46	0.64	0.54	0.06
Oct	0.50	0.43	0.47	0.45	0.09
Nov	0.29	0.34	0.39	0.35	0.07
Dec	0.30	0.32	0.36	0.35	0.10
Jan	0.32	0.33	0.36	0.35	0.11
Mean	**0.41**	**0.39**	**0.42**	**0.43**	**0.08**
S.D	**0.11**	**0.07**	**0.10**	**0.09**	**0.02**

Source: Field work

Appendix 5.55: Mean Concentrations of Magnesium in Stemflow in mg l^{-1}

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest	Incident Rainfall
Feb	4.7	3.5	4.6	4.8	2.7
Mar	4.8	3.6	4.7	4.8	2.8
Apr	4.2	4.1	4.0	4.3	2.4
May	4.7	3.9	4.1	4.1	2.0
Jun	4.6	3.9	4.0	4.7	1.8
Jul	5.0	4.5	4.7	4.9	1.6
Aug	5.1	4.2	4.6	4.9	1.8
Sep	5.4	4.2	4.7	5.3	1.4
Oct	5.2	3.9	4.7	5.1	1.9
Nov	4.1	3.8	3.7	3.9	2.1
Dec	4.8	3.6	4.5	4.6	2.7
Jan	4.7	3.6	4.5	4.9	2.7
Mean	**4.78**	**3.90**	**4.40**	**4.69**	**2.l6**
S.D	**0.38**	**0.31**	**0.35**	**0.41**	**0.49**

Source: Field work

Appendix 5.56: ANOVA and Monthly pH values in Stemflow

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest	Incident Rainfall
Feb	5.8	5.5	5.0	5.1	6.0
Mar	5.7	5.8	5.0	5.0	5.9
Apr	5.8	5.0	4.8	5.1	6.1
May	5.3	5.1	5.1	5.2	6.0
Jun	5.1	5.6	4.9	5.3	6.2
Jul	5.0	5.0	4.7	5.9	6.2
Aug	5.6	5.9	5.0	6.0	6.1
Sep	5.4	5.1	4.7	5.7	6.2
Oct	5.0	5.1	4.8	5.7	6.3
Nov	5.2	5.0	4.6	5.0	5.9
Dec	5.2	5.7	5.1	5.8	6.2
Jan	5.7	5.7	5.1	5.3	6.0
Mean	**5.40**	**5.38**	**4.90**	**5.43**	**6.09**

Source: Field work

ANOVA

phsf

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8.668	4	2.167	26.757	.000
Within Groups	4.454	55	.081		
Total	13.122	59			

Appendix 5.57: Multiple comparisons using the LSD test: Nitrogen concentrations in stemflow

Multiple Comparisons

Dependent Variable: stands
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.21250*	.04351	.000	.1253	.2997
	3.00	.09417*	.04351	.035	.0070	.1814
	4.00	-.05833	.04351	.186	-.1455	.0289
	5.00	.44333*	.04351	.000	.3561	.5305
2.00	1.00	-.21250*	.04351	.000	-.2997	-.1253
	3.00	-.11833*	.04351	.009	-.2055	-.0311
	4.00	-.27083*	.04351	.000	-.3580	-.1836
	5.00	.23083*	.04351	.000	.1436	.3180
3.00	1.00	-.09417*	.04351	.035	-.1814	-.0070
	2.00	.11833*	.04351	.009	.0311	.2055
	4.00	-.15250*	.04351	.001	-.2397	-.0653
	5.00	.34917*	.04351	.000	.2620	.4364
4.00	1.00	.05833	.04351	.186	-.0289	.1455
	2.00	.27083*	.04351	.000	.1836	.3580
	3.00	.15250*	.04351	.001	.0653	.2397
	5.00	.50167*	.04351	.000	.4145	.5889
5.00	1.00	-.44333*	.04351	.000	-.5305	-.3561
	2.00	-.23083*	.04351	.000	-.3180	-.1436
	3.00	-.34917*	.04351	.000	-.4364	-.2620
	4.00	-.50167*	.04351	.000	-.5889	-.4145

*. The mean difference is significant at the .05 level.

1, 2, 3, 4, 5, represent Indian almond, Mango, Avocado pear, adjoining rainforest and incident rainfall respectively

Appendix 5.58: Multiple comparisons with LSD test: Phosphorus concentrations in stemflow

Multiple Comparisons

Dependent Variable: stands
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.09083*	.04140	.032	-.1738	-.0079
	3.00	.14833*	.04140	.001	.0654	.2313
	4.00	-.00167	.04140	.968	-.0846	.0813
	5.00	.38750*	.04140	.000	.3045	.4705
2.00	1.00	.09083*	.04140	.032	.0079	.1738
	3.00	.23917*	.04140	.000	.1562	.3221
	4.00	.08917*	.04140	.036	.0062	.1721
	5.00	.47833*	.04140	.000	.3954	.5613
3.00	1.00	-.14833*	.04140	.001	-.2313	-.0654
	2.00	-.23917*	.04140	.000	-.3221	-.1562
	4.00	-.15000*	.04140	.001	-.2330	-.0670
	5.00	.23917*	.04140	.000	.1562	.3221
4.00	1.00	.00167	.04140	.968	-.0813	.0846
	2.00	-.08917*	.04140	.036	-.1721	-.0062
	3.00	.15000*	.04140	.001	.0670	.2330
	5.00	.38917*	.04140	.000	.3062	.4721
5.00	1.00	-.38750*	.04140	.000	-.4705	-.3045
	2.00	-.47833*	.04140	.000	-.5613	-.3954
	3.00	-.23917*	.04140	.000	-.3221	-.1562
	4.00	-.38917*	.04140	.000	-.4721	-.3062

*. The mean difference is significant at the .05 level.

1, 2, 3, 4, 5, represent Indian almond, Mango, Avocado pear, adjoining rainforest and incident rainfall respectively

Appendix 5.59: Multiple comparisons with LSD test: Potassium concentrations in stemflow

Multiple Comparisons

Dependent Variable: stands
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	1.97500*	.50383	.000	.9653	2.9847
	3.00	1.02500*	.50383	.047	.0153	2.0347
	4.00	.21667	.50383	.669	-.7930	1.2264
	5.00	9.90000*	.50383	.000	8.8903	10.9097
2.00	1.00	-1.97500*	.50383	.000	-2.9847	-.9653
	3.00	-.95000	.50383	.065	-1.9597	.0597
	4.00	-1.75833*	.50383	.001	-2.7680	-.7486
	5.00	7.92500*	.50383	.000	6.9153	8.9347
3.00	1.00	-1.02500*	.50383	.047	-2.0347	-.0153
	2.00	.95000	.50383	.065	-.0597	1.9597
	4.00	-.80833	.50383	.114	-1.8180	.2014
	5.00	8.87500*	.50383	.000	7.8653	9.8847
4.00	1.00	-.21667	.50383	.669	-1.2264	.7930
	2.00	1.75833*	.50383	.001	.7486	2.7680
	3.00	.80833	.50383	.114	-.2014	1.8180
	5.00	9.68333*	.50383	.000	8.6736	10.6930
5.00	1.00	-9.90000*	.50383	.000	-10.9097	-8.8903
	2.00	-7.92500*	.50383	.000	-8.9347	-6.9153
	3.00	-8.87500*	.50383	.000	-9.8847	-7.8653
	4.00	-9.68333*	.50383	.000	-10.6930	-8.6736

*. The mean difference is significant at the .05 level.

1, 2, 3, 4, 5, represent Indian almond, Mango, Avocado pear, adjoining rainforest and incident rainfall respectively

Appendix 5.60: Multiple comparisons with LSD test: Calcium concentrations in stemflow

Multiple Comparisons

Dependent Variable: stands
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.80000*	.37483	.037	.0488	1.5512
	3.00	.04167	.37483	.912	-.7095	.7928
	4.00	.41667	.37483	.271	-.3345	1.1678
	5.00	4.12500*	.37483	.000	3.3738	4.8762
2.00	1.00	-.80000*	.37483	.037	-1.5512	-.0488
	3.00	-.75833*	.37483	.048	-1.5095	-.0072
	4.00	-.38333	.37483	.311	-1.1345	.3678
	5.00	3.32500*	.37483	.000	2.5738	4.0762
3.00	1.00	-.04167	.37483	.912	-.7928	.7095
	2.00	.75833*	.37483	.048	.0072	1.5095
	4.00	.37500	.37483	.321	-.3762	1.1262
	5.00	4.08333*	.37483	.000	3.3322	4.8345
4.00	1.00	-.41667	.37483	.271	-1.1678	.3345
	2.00	.38333	.37483	.311	-.3678	1.1345
	3.00	-.37500	.37483	.321	-1.1262	.3762
	5.00	3.70833*	.37483	.000	2.9572	4.4595
5.00	1.00	-4.12500*	.37483	.000	-4.8762	-3.3738
	2.00	-3.32500*	.37483	.000	-4.0762	-2.5738
	3.00	-4.08333*	.37483	.000	-4.8345	-3.3322
	4.00	-3.70833*	.37483	.000	-4.4595	-2.9572

*. The mean difference is significant at the .05 level.

1, 2, 3, 4, 5, represent Indian almond, Mango, Avocado pear, adjoining rainforest and incident rainfall respectively

Appendix 5.61: Multiple comparisons with LSD test: Sodium concentrations in stemflow

Multiple Comparisons

Dependent Variable: stands
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.01500	.03407	.661	-.0533	.0833
	3.00	-.01833	.03407	.593	-.0866	.0499
	4.00	-.02917	.03407	.396	-.0974	.0391
	5.00	.32250*	.03407	.000	.2542	.3908
2.00	1.00	-.01500	.03407	.661	-.0833	.0533
	3.00	-.03333	.03407	.332	-.1016	.0349
	4.00	-.04417	.03407	.200	-.1124	.0241
	5.00	.30750*	.03407	.000	.2392	.3758
3.00	1.00	.01833	.03407	.593	-.0499	.0866
	2.00	.03333	.03407	.332	-.0349	.1016
	4.00	-.01083	.03407	.752	-.0791	.0574
	5.00	.34083*	.03407	.000	.2726	.4091
4.00	1.00	.02917	.03407	.396	-.0391	.0974
	2.00	.04417	.03407	.200	-.0241	.1124
	3.00	.01083	.03407	.752	-.0574	.0791
	5.00	.35167*	.03407	.000	.2834	.4199
5.00	1.00	-.32250*	.03407	.000	-.3908	-.2542
	2.00	-.30750*	.03407	.000	-.3758	-.2392
	3.00	-.34083*	.03407	.000	-.4091	-.2726
	4.00	-.35167*	.03407	.000	-.4199	-.2834

*. The mean difference is significant at the .05 level.

1, 2, 3, 4, 5, represent Indian almond, Mango, Avocado pear, adjoining rainforest and incident rainfall respectively

Appendix 5.62: Multiple comparisons with LSD test: Magnesium concentrations in stemflow

Multiple Comparisons

Dependent Variable: stands
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.87500*	.15917	.000	.5560	1.1940
	3.00	.37500*	.15917	.022	.0560	.6940
	4.00	.08333	.15917	.603	-.2357	.4023
	5.00	2.61667*	.15917	.000	2.2977	2.9357
2.00	1.00	-.87500*	.15917	.000	-1.1940	-.5560
	3.00	-.50000*	.15917	.003	-.8190	-.1810
	4.00	-.79167*	.15917	.000	-1.1107	-.4727
	5.00	1.74167*	.15917	.000	1.4227	2.0607
3.00	1.00	-.37500*	.15917	.022	-.6940	-.0560
	2.00	.50000*	.15917	.003	.1810	.8190
	4.00	-.29167	.15917	.072	-.6107	.0273
	5.00	2.24167*	.15917	.000	1.9227	2.5607
4.00	1.00	-.08333	.15917	.603	-.4023	.2357
	2.00	.79167*	.15917	.000	.4727	1.1107
	3.00	.29167	.15917	.072	-.0273	.6107
	5.00	2.53333*	.15917	.000	2.2143	2.8523
5.00	1.00	-2.61667*	.15917	.000	-2.9357	-2.2977
	2.00	-1.74167*	.15917	.000	-2.0607	-1.4227
	3.00	-2.24167*	.15917	.000	-2.5607	-1.9227
	4.00	-2.53333*	.15917	.000	-2.8523	-2.2143

*. The mean difference is significant at the .05 level.

1, 2, 3, 4, 5, represent Indian almond, Mango, Avocado pear, adjoining rainforest and incident rainfall respectively

Appendix 5.63: Multiple comparisons with LSD test: pH values in stemflow

Multiple Comparisons

Dependent Variable: stands
LSD

(I) samplesites	(J) samplesites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.02500	.11618	.830	-.2078	.2578
	3.00	.50000*	.11618	.000	.2672	.7328
	4.00	-.02500	.11618	.830	-.2578	.2078
	5.00	-.69167*	.11618	.000	-.9245	-.4588
2.00	1.00	-.02500	.11618	.830	-.2578	.2078
	3.00	.47500*	.11618	.000	.2422	.7078
	4.00	-.05000	.11618	.669	-.2828	.1828
	5.00	-.71667*	.11618	.000	-.9495	-.4838
3.00	1.00	-.50000*	.11618	.000	-.7328	-.2672
	2.00	-.47500*	.11618	.000	-.7078	-.2422
	4.00	-.52500*	.11618	.000	-.7578	-.2922
	5.00	-1.19167*	.11618	.000	-1.4245	-.9588
4.00	1.00	.02500	.11618	.830	-.2078	.2578
	2.00	.05000	.11618	.669	-.1828	.2828
	3.00	.52500*	.11618	.000	.2922	.7578
	5.00	-.66667*	.11618	.000	-.8995	-.4338
5.00	1.00	.69167*	.11618	.000	.4588	.9245
	2.00	.71667*	.11618	.000	.4838	.9495
	3.00	1.19167*	.11618	.000	.9588	1.4245
	4.00	.66667*	.11618	.000	.4338	.8995

*. The mean difference is significant at the .05 level.

1, 2, 3, 4, 5, represent Indian almond, Mango, Avocado pear, adjoining rainforest and incident rainfall respectively

Appendix 5.64: Mean Monthly Return of Nitrogen to the Soil via Stemflow in kg/ha

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	0.16	0.08	0.04	0.16
Mar	0.17	0.12	0.06	0.20
Apr	0.46	0.15	0.09	0.43
May	0.54	0.21	0.18	0.56
Jun	0.60	0.30	0.31	0.74
Jul	0.60	0.53	0.41	0.82
Aug	0.46	0.35	0.23	0.52
Sep	0.62	0.56	0.38	0.86
Oct	0.48	0.38	0.16	0.67
Nov	0.27	0.16	0.12	0.35
Dec	0.18	0.08	0.04	0.17
Jan	0.16	0.07	0.04	0.16
Mean	**0.39**	**0.25**	**0.17**	**0.47**
S.D	**0.19**	**0.17**	**0.13**	**0.26**

Source: Field work

Appendix 5.65: Mean Monthly Return of Phosphorus to the Soil via Stemflow in kg/ha

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	0.01	0.01	0.02	0.02
Mar	0.02	0.02	0.02	0.04
Apr	0.03	0.04	0.03	0.06
May	0.06	0.04	0.05	0.09
Jun	0.07	0.06	0.05	0.12
Jul	0.13	0.08	0.06	0.16
Aug	0.06	0.03	0.02	0.07
Sep	0.12	0.08	0.05	0.18
Oct	0.05	0.04	0.03	0.08
Nov	0.03	0.03	0.02	0.08
Dec	0.01	0.02	0.01	0.03
Jan	0.01	0.01	0.01	0.02
Mean	**0.05**	**0.04**	**0.03**	**0.08**
S.D	**0.04**	**0.02**	**0.02**	**0.05**

Source: Field work

Appendix 5.66: Mean Monthly Return of Potassium to the Soil via Stemflow in kg/ha

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	0.3	0.1	0.1	0.2
Mar	0.4	0.1	0.2	0.3
Apr	0.6	0.2	0.2	0.5
May	0.5	0.2	0.4	0.5
Jun	0.9	0.3	0.4	0.9
Jul	1.3	0.8	0.8	1.2
Aug	1.0	0.7	0.6	1.0
Sep	1.4	0.7	0.7	1.4
Oct	0.9	0.3	0.4	1.0
Nov	0.4	0.2	0.3	0.6
Dec	0.3	0.1	0.1	0.2
Jan	0.3	0.1	0.1	0.2
Mean	**0.69**	**0.32**	**0.36**	**0.67**
S.D	**0.40**	**0.26**	**0.24**	**0.42**

Source: Field work

Appendix 5.67: Mean Monthly Return of Calcium to the Soil via Stemflow in kg/ha

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	0.22	0.09	0.17	0.11
Mar	0.34	0.19	0.20	0.12
Apr	0.51	0.28	0.46	0.21
May	0.82	0.36	0.67	0.24
Jun	1.04	0.62	0.94	0.32
Jul	1.13	0.87	1.19	0.56
Aug	1.02	0.74	0.96	0.52
Sep	1.21	0.92	1.14	0.59
Oct	0.94	0.46	0.84	0.33
Nov	0.48	0.21	0.52	0.14
Dec	0.23	0.18	0.19	0.11
Jan	0.21	0.08	0.19	0.09
Mean	**0.68**	**0.42**	**0.62**	**0.28**
S.D	**0.39**	**0.30**	**0.39**	**0.19**

Source: Field work

Appendix 5.68: Mean Monthly Return of Sodium to the Soil via Stemflow in kg/ha

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	0.02	0.01	0.03	0.04
Mar	0.04	0.02	0.05	0.05
Apr	0.06	0.03	0.07	0.09
May	0.08	0.05	0.10	0.16
Jun	0.10	0.07	0.16	0.18
Jul	0.13	0.09	0.18	0.26
Aug	0.10	0.07	0.18	0.24
Sep	0.12	0.10	0.20	0.27
Oct	0.08	0.03	0.16	0.16
Nov	0.04	0.02	0.08	0.09
Dec	0.02	0.01	0.04	0.06
Jan	0.02	0.01	0.03	0.04
Mean	**0.07**	**0.04**	**0.11**	**0.14**
S.D	**0.04**	**0.03**	**0.07**	**0.09**

Source: Field work

Appendix 5.69: Mean Monthly Return of Magnesium to the Soil via Stemflow in kg/ha

Months	Indian Almond (*Terminalia cattapa*)	Mango (*Mangifera indica*)	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	0.34	0.08	0.09	0.07
Mar	0.47	0.10	0.13	0.20
Apr	0.61	0.14	0.43	0.32
May	1.01	0.18	0.74	0.60
Jun	1.24	0.23	1.11	0.92
Jul	1.33	0.57	1.18	1.12
Aug	1.24	0.55	1.16	1.10
Sep	1.32	0.58	1.19	1.12
Oct	1.18	0.38	0.67	0.91
Nov	0.52	0.16	0.32	0.08
Dec	0.39	0.07	0.11	0.08
Jan	0.32	0.07	0.09	0.06
Mean	**0.83**	**0.26**	**0.60**	**0.55**
S.D	**0.42**	**0.20**	**0.46**	**0.46**

Source: Field work

Appendix 5.70: Multiple comparisons with LSD test: Nitrogen returns in stemflow

Multiple Comparisons

Dependent Variable: Nreturns
LSD

(I) sites	(J) sites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.14250	.08003	.082	-.0188	.3038
	3.00	.22000*	.08003	.009	.0587	.3813
	4.00	-.07833	.08003	.333	-.2396	.0830
2.00	1.00	-.14250	.08003	.082	-.3038	.0188
	3.00	.07750	.08003	.338	-.0838	.2388
	4.00	-.22083*	.08003	.008	-.3821	-.0595
3.00	1.00	-.22000*	.08003	.009	-.3813	-.0587
	2.00	-.07750	.08003	.338	-.2388	.0838
	4.00	-.29833*	.08003	.001	-.4596	-.1370
4.00	1.00	.07833	.08003	.333	-.0830	.2396
	2.00	.22083*	.08003	.008	.0595	.3821
	3.00	.29833*	.08003	.001	.1370	.4596

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Indian almond, Mango, Avocado pear and adjoining rainforest respectively

Appendix 5.71: Multiple comparisons with LSD test: Phosphorus returns in stemflow

Multiple Comparisons

Dependent Variable: Preturns
LSD

(I) sites	(J) sites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.01167	.01482	.435	-.0182	.0415
	3.00	.01917	.01482	.203	-.0107	.0490
	4.00	-.02917	.01482	.055	-.0590	.0007
2.00	1.00	-.01167	.01482	.435	-.0415	.0182
	3.00	.00750	.01482	.615	-.0224	.0374
	4.00	-.04083*	.01482	.008	-.0707	-.0110
3.00	1.00	-.01917	.01482	.203	-.0490	.0107
	2.00	-.00750	.01482	.615	-.0374	.0224
	4.00	-.04833*	.01482	.002	-.0782	-.0185
4.00	1.00	.02917	.01482	.055	-.0007	.0590
	2.00	.04083*	.01482	.008	.0110	.0707
	3.00	.04833*	.01482	.002	.0185	.0782

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Indian almond, Mango, Avocado pear and adjoining rainforest respectively

Appendix 5.72: Multiple comparisons with LSD test: **Potassium returns in stemflow**

Multiple Comparisons

Dependent Variable: Kreturns
LSD

(I) sites	(J) sites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.37500*	.13847	.010	.0959	.6541
	3.00	.33333*	.13847	.020	.0543	.6124
	4.00	.02500	.13847	.858	-.2541	.3041
2.00	1.00	-.37500*	.13847	.010	-.6541	-.0959
	3.00	-.04167	.13847	.765	-.3207	.2374
	4.00	-.35000*	.13847	.015	-.6291	-.0709
3.00	1.00	-.33333*	.13847	.020	-.6124	-.0543
	2.00	.04167	.13847	.765	-.2374	.3207
	4.00	-.30833*	.13847	.031	-.5874	-.0293
4.00	1.00	-.02500	.13847	.858	-.3041	.2541
	2.00	.35000*	.13847	.015	.0709	.6291
	3.00	.30833*	.13847	.031	.0293	.5874

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Indian almond, Mango, Avocado pear and adjoining rainforest respectively

Appendix 5.73: Multiple comparisons with LSD test: **Calcium returns in stemflow**

Multiple Comparisons

Dependent Variable: Careturns
LSD

(I) sites	(J) sites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.26250	.13292	.055	-.0054	.5304
	3.00	.05667	.13292	.672	-.2112	.3245
	4.00	.40083*	.13292	.004	.1330	.6687
2.00	1.00	-.26250	.13292	.055	-.5304	.0054
	3.00	-.20583	.13292	.129	-.4737	.0620
	4.00	.13833	.13292	.304	-.1295	.4062
3.00	1.00	-.05667	.13292	.672	-.3245	.2112
	2.00	.20583	.13292	.129	-.0620	.4737
	4.00	.34417*	.13292	.013	.0763	.6120
4.00	1.00	-.40083*	.13292	.004	-.6687	-.1330
	2.00	-.13833	.13292	.304	-.4062	.1295
	3.00	-.34417*	.13292	.013	-.6120	-.0763

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Indian almond, Mango, Avocado pear and adjoining rainforest respectively

Appendix 5.74: Multiple comparisons with LSD test: Sodium returns in stemflow

Multiple Comparisons

Dependent Variable: Nareturns
LSD

(I) sites	(J) sites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.02500	.02452	.314	-.0244	.0744
	3.00	-.03917	.02452	.117	-.0886	.0103
	4.00	-.06917*	.02452	.007	-.1186	-.0197
2.00	1.00	-.02500	.02452	.314	-.0744	.0244
	3.00	-.06417*	.02452	.012	-.1136	-.0147
	4.00	-.09417*	.02452	.000	-.1436	-.0447
3.00	1.00	.03917	.02452	.117	-.0103	.0886
	2.00	.06417*	.02452	.012	.0147	.1136
	4.00	-.03000	.02452	.228	-.0794	.0194
4.00	1.00	.06917*	.02452	.007	.0197	.1186
	2.00	.09417*	.02452	.000	.0447	.1436
	3.00	.03000	.02452	.228	-.0194	.0794

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Indian almond, Mango, Avocado pear and adjoining rainforest respectively

Appendix 5.75: Multiple comparisons with LSD test: Magnesium returns in stemflow

Multiple Comparisons

Dependent Variable: Mgreturns
LSD

(I) sites	(J) sites	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.57167*	.16386	.001	.2414	.9019
	3.00	.22917	.16386	.169	-.1011	.5594
	4.00	.28250	.16386	.092	-.0477	.6127
2.00	1.00	-.57167*	.16386	.001	-.9019	-.2414
	3.00	-.34250*	.16386	.042	-.6727	-.0123
	4.00	-.28917	.16386	.085	-.6194	.0411
3.00	1.00	-.22917	.16386	.169	-.5594	.1011
	2.00	.34250*	.16386	.042	.0123	.6727
	4.00	.05333	.16386	.746	-.2769	.3836
4.00	1.00	-.28250	.16386	.092	-.6127	.0477
	2.00	.28917	.16386	.085	-.0411	.6194
	3.00	-.05333	.16386	.746	-.3836	.2769

*. The mean difference is significant at the .05 level.

1, 2, 3 and 4 represent Indian almond, Mango, Avocado pear and adjoining rainforest respectively

Appendix 5.76: Multiple comparisons with LSD test: Nitrogen returns via litterfall, throughfall and stemflow in Indian almond

Multiple Comparisons

Dependent Variable: Nitrogen
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.86833	1.22677	.484	-1.6275	3.3642
	3.00	5.33500*	1.22677	.000	2.8391	7.8309
2.00	1.00	-.86833	1.22677	.484	-3.3642	1.6275
	3.00	4.46667*	1.22677	.001	1.9708	6.9625
3.00	1.00	-5.33500*	1.22677	.000	-7.8309	-2.8391
	2.00	-4.46667*	1.22677	.001	-6.9625	-1.9708

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.77: Multiple comparisons with LSD test: Nitrogen returns via litterfall, throughfall and stemflow in mango

Multiple Comparisons

Dependent Variable: Nitrogen
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.00167	.39723	.997	-.8065	.8098
	3.00	3.22750*	.39723	.000	2.4193	4.0357
2.00	1.00	-.00167	.39723	.997	-.8098	.8065
	3.00	3.22583*	.39723	.000	2.4177	4.0340
3.00	1.00	-3.22750*	.39723	.000	-4.0357	-2.4193
	2.00	-3.22583*	.39723	.000	-4.0340	-2.4177

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.78: Multiple comparisons with LSD test: Nitrogen returns via litterfall, throughfall and stemflow in Pear

Multiple Comparisons

Dependent Variable: Nitrogen
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.22417	.19286	.253	-.1682	.6165
	3.00	2.24417*	.19286	.000	1.8518	2.6365
2.00	1.00	-.22417	.19286	.253	-.6165	.1682
	3.00	2.02000*	.19286	.000	1.6276	2.4124
3.00	1.00	-2.24417*	.19286	.000	-2.6365	-1.8518
	2.00	-2.02000*	.19286	.000	-2.4124	-1.6276

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.79: Multiple comparisons with LSD test: Nitrogen returns via litterfall, throughfall and stemflow in Forest

Multiple Comparisons

Dependent Variable: Nitrogen
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	3.03500*	1.44110	.043	.1031	5.9669
	3.00	8.60667*	1.44110	.000	5.6747	11.5386
2.00	1.00	-3.03500*	1.44110	.043	-5.9669	-.1031
	3.00	5.57167*	1.44110	.000	2.6397	8.5036
3.00	1.00	-8.60667*	1.44110	.000	-11.5386	-5.6747
	2.00	-5.57167*	1.44110	.000	-8.5036	-2.6397

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.80: Multiple comparisons with LSD test: Phosphorus returns via litterfall, throughfall and stemflow in Indian almond

Multiple Comparisons

Dependent Variable: phosphorus
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.01917	.15419	.902	-.3329	.2945
	3.00	.59750*	.15419	.000	.2838	.9112
2.00	1.00	.01917	.15419	.902	-.2945	.3329
	3.00	.61667*	.15419	.000	.3030	.9304
3.00	1.00	-.59750*	.15419	.000	-.9112	-.2838
	2.00	-.61667*	.15419	.000	-.9304	-.3030

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.81: Multiple comparisons with LSD test: Phosphorus returns via litterfall, throughfall and stemflow in mango

Multiple Comparisons

Dependent Variable: phosphorus
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.32833*	.09934	.002	-.5305	-.1262
	3.00	.40833*	.09934	.000	.2062	.6105
2.00	1.00	.32833*	.09934	.002	.1262	.5305
	3.00	.73667*	.09934	.000	.5345	.9388
3.00	1.00	-.40833*	.09934	.000	-.6105	-.2062
	2.00	-.73667*	.09934	.000	-.9388	-.5345

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.82: Multiple comparisons with LSD test: Phosphorus returns via litterfall, throughfall and stemflow in Pear

Multiple Comparisons

Dependent Variable: phosphorus
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.10333	.05820	.085	-.0151	.2217
	3.00	.38917*	.05820	.000	.2708	.5076
2.00	1.00	-.10333	.05820	.085	-.2217	.0151
	3.00	.28583*	.05820	.000	.1674	.4042
3.00	1.00	-.38917*	.05820	.000	-.5076	-.2708
	2.00	-.28583*	.05820	.000	-.4042	-.1674

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.83: Multiple comparisons with LSD test: Phosphorus returns via litterfall, throughfall and stemflow in forest

Multiple Comparisons

Dependent Variable: phosphorus
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.06417	.11896	.593	-.1779	.3062
	3.00	.51833*	.11896	.000	.2763	.7604
2.00	1.00	-.06417	.11896	.593	-.3062	.1779
	3.00	.45417*	.11896	.001	.2121	.6962
3.00	1.00	-.51833*	.11896	.000	-.7604	-.2763
	2.00	-.45417*	.11896	.001	-.6962	-.2121

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.84: Multiple comparisons with LSD test: Potassium returns via litterfall, throughfall and stemflow in Indian almond

Multiple Comparisons

Dependent Variable: potassium
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-5.63000*	1.21457	.000	-8.1011	-3.1589
	3.00	4.22833*	1.21457	.001	1.7573	6.6994
2.00	1.00	5.63000*	1.21457	.000	3.1589	8.1011
	3.00	9.85833*	1.21457	.000	7.3873	12.3294
3.00	1.00	-4.22833*	1.21457	.001	-6.6994	-1.7573
	2.00	-9.85833*	1.21457	.000	-12.3294	-7.3873

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.85: Multiple comparisons with LSD test: Potassium returns via litterfall, throughfall and stemflow in Mango

Multiple Comparisons

Dependent Variable: potassium
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-6.82500*	.45897	.000	-7.7588	-5.8912
	3.00	2.32500*	.45897	.000	1.3912	3.2588
2.00	1.00	6.82500*	.45897	.000	5.8912	7.7588
	3.00	9.15000*	.45897	.000	8.2162	10.0838
3.00	1.00	-2.32500*	.45897	.000	-3.2588	-1.3912
	2.00	-9.15000*	.45897	.000	-10.0838	-8.2162

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.86: Multiple comparisons with LSD test: Potassium returns via litterfall, throughfall and stemflow in Pear

Multiple Comparisons

Dependent Variable: potassium
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-5.22500*	.72070	.000	-6.6913	-3.7587
	3.00	1.78333*	.72070	.019	.3171	3.2496
2.00	1.00	5.22500*	.72070	.000	3.7587	6.6913
	3.00	7.00833*	.72070	.000	5.5421	8.4746
3.00	1.00	-1.78333*	.72070	.019	-3.2496	-.3171
	2.00	-7.00833*	.72070	.000	-8.4746	-5.5421

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.87: Multiple comparisons with LSD test: Potassium returns via litterfall, throughfall and stemflow in forest

Multiple Comparisons

Dependent Variable: potassium
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-5.36750*	1.05335	.000	-7.5106	-3.2244
	3.00	2.72417*	1.05335	.014	.5811	4.8672
2.00	1.00	5.36750*	1.05335	.000	3.2244	7.5106
	3.00	8.09167*	1.05335	.000	5.9486	10.2347
3.00	1.00	-2.72417*	1.05335	.014	-4.8672	-.5811
	2.00	-8.09167*	1.05335	.000	-10.2347	-5.9486

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.88: Multiple comparisons with LSD test: Calcium returns via litterfall, throughfall and stemflow in Indian almond

Multiple Comparisons

Dependent Variable: Calcium
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.65667	1.70077	.702	-2.8036	4.1169
	3.00	6.81917*	1.70077	.000	3.3589	10.2794
2.00	1.00	-.65667	1.70077	.702	-4.1169	2.8036
	3.00	6.16250*	1.70077	.001	2.7023	9.6227
3.00	1.00	-6.81917*	1.70077	.000	-10.2794	-3.3589
	2.00	-6.16250*	1.70077	.001	-9.6227	-2.7023

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.89: Multiple comparisons with LSD test: Calcium returns via litterfall, throughfall and stemflow in Mango

Multiple Comparisons

Dependent Variable: Calcium
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.54750	.79179	.494	-2.1584	1.0634
	3.00	4.80250*	.79179	.000	3.1916	6.4134
2.00	1.00	.54750	.79179	.494	-1.0634	2.1584
	3.00	5.35000*	.79179	.000	3.7391	6.9609
3.00	1.00	-4.80250*	.79179	.000	-6.4134	-3.1916
	2.00	-5.35000*	.79179	.000	-6.9609	-3.7391

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.90: Multiple comparisons with LSD test: Calcium returns via litterfall, throughfall and stemflow in Pear

Multiple Comparisons

Dependent Variable: Calcium
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	1.29333	.73274	.087	-.1974	2.7841
	3.00	4.74583*	.73274	.000	3.2551	6.2366
2.00	1.00	-1.29333	.73274	.087	-2.7841	.1974
	3.00	3.45250*	.73274	.000	1.9617	4.9433
3.00	1.00	-4.74583*	.73274	.000	-6.2366	-3.2551
	2.00	-3.45250*	.73274	.000	-4.9433	-1.9617

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.91: Multiple comparisons with LSD test: Calcium returns via litterfall, throughfall and stemflow in forest

Multiple Comparisons

Dependent Variable: Calcium
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	3.34083*	1.25671	.012	.7840	5.8976
	3.00	7.52917*	1.25671	.000	4.9724	10.0860
2.00	1.00	-3.34083*	1.25671	.012	-5.8976	-.7840
	3.00	4.18833*	1.25671	.002	1.6315	6.7451
3.00	1.00	-7.52917*	1.25671	.000	-10.0860	-4.9724
	2.00	-4.18833*	1.25671	.002	-6.7451	-1.6315

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.91: Multiple comparisons with LSD test: Sodium returns via litterfall, throughfall and stemflow in Indian almond

Multiple Comparisons

Dependent Variable: sodium
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.05167	.11755	.663	-.2908	.1875
	3.00	.34083*	.11755	.007	.1017	.5800
2.00	1.00	.05167	.11755	.663	-.1875	.2908
	3.00	.39250*	.11755	.002	.1533	.6317
3.00	1.00	-.34083*	.11755	.007	-.5800	-.1017
	2.00	-.39250*	.11755	.002	-.6317	-.1533

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.92: Multiple comparisons with LSD test: Sodium returns via litterfall, throughfall and stemflow in Mango

Multiple Comparisons

Dependent Variable: sodium
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.56000*	.09496	.000	-.7532	-.3668
	3.00	.20333*	.09496	.040	.0101	.3965
2.00	1.00	.56000*	.09496	.000	.3668	.7532
	3.00	.76333*	.09496	.000	.5701	.9565
3.00	1.00	-.20333*	.09496	.040	-.3965	-.0101
	2.00	-.76333*	.09496	.000	-.9565	-.5701

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.93: Multiple comparisons with LSD test: Sodium returns via litterfall, throughfall and stemflow in Pear

Multiple Comparisons

Dependent Variable: sodium
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.53917*	.10655	.000	-.7559	-.3224
	3.00	.20667	.10655	.061	-.0101	.4234
2.00	1.00	.53917*	.10655	.000	.3224	.7559
	3.00	.74583*	.10655	.000	.5291	.9626
3.00	1.00	-.20667	.10655	.061	-.4234	.0101
	2.00	-.74583*	.10655	.000	-.9626	-.5291

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.94: Multiple comparisons with LSD test: Sodium returns via litterfall, throughfall and stemflow in Forest

Multiple Comparisons

Dependent Variable: sodium
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.16167	.12422	.202	-.4144	.0911
	3.00	.35083*	.12422	.008	.0981	.6036
2.00	1.00	.16167	.12422	.202	-.0911	.4144
	3.00	.51250*	.12422	.000	.2598	.7652
3.00	1.00	-.35083*	.12422	.008	-.6036	-.0981
	2.00	-.51250*	.12422	.000	-.7652	-.2598

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.95: Multiple comparisons with LSD test: Magnesium returns via litterfall, throughfall and stemflow in Indian almond

Multiple Comparisons

Dependent Variable: magnesium
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-1.93833*	.80196	.021	-3.5699	-.3067
	3.00	1.39083	.80196	.092	-.2408	3.0224
2.00	1.00	1.93833*	.80196	.021	.3067	3.5699
	3.00	3.32917*	.80196	.000	1.6976	4.9608
3.00	1.00	-1.39083	.80196	.092	-3.0224	.2408
	2.00	-3.32917*	.80196	.000	-4.9608	-1.6976

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.96: Multiple comparisons with LSD test: Magnesium returns via litterfall, throughfall and stemflow in Mango

Multiple Comparisons

Dependent Variable: magnesium
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-1.00167*	.30637	.003	-1.6250	-.3783
	3.00	.91167*	.30637	.005	.2883	1.5350
2.00	1.00	1.00167*	.30637	.003	.3783	1.6250
	3.00	1.91333*	.30637	.000	1.2900	2.5367
3.00	1.00	-.91167*	.30637	.005	-1.5350	-.2883
	2.00	-1.91333*	.30637	.000	-2.5367	-1.2900

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.97: Multiple comparisons with LSD test: Magnesium returns via litterfall, throughfall and stemflow in Pear

Multiple Comparisons

Dependent Variable: magnesium
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-2.77583*	.66630	.000	-4.1314	-1.4202
	3.00	1.27167	.66630	.065	-.0839	2.6273
2.00	1.00	2.77583*	.66630	.000	1.4202	4.1314
	3.00	4.04750*	.66630	.000	2.6919	5.4031
3.00	1.00	-1.27167	.66630	.065	-2.6273	.0839
	2.00	-4.04750*	.66630	.000	-5.4031	-2.6919

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.98: Multiple comparisons with LSD test: Magnesium returns via litterfall, throughfall and stemflow in forest

Multiple Comparisons

Dependent Variable: magnesium
LSD

(I) stands	(J) stands	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.43667	.43119	.319	-.4406	1.3139
	3.00	2.02083*	.43119	.000	1.1436	2.8981
2.00	1.00	-.43667	.43119	.319	-1.3139	.4406
	3.00	1.58417*	.43119	.001	.7069	2.4614
3.00	1.00	-2.02083*	.43119	.000	-2.8981	-1.1436
	2.00	-1.58417*	.43119	.001	-2.4614	-.7069

*. The mean difference is significant at the .05 level.

1, 2 and 3 represent litterfall, throughfall and stemflow respectively

Appendix 5.99: Volume of Throughfall in mm

Months	Almond	Mango	Pear	Rainforest	Incident rainfall
February	96.74	96.31	98.92	91.53	108.7
March	251.43	250.30	257.08	237.87	282.5
April	377.89	376.20	386.39	357.51	424.6
May	409.22	407.38	418.42	387.15	459.8
June	570.85	56.83	492.67	540.06	641.4
July	723.57	720.32	739.83	684.56	813.0
August	359.65	358.03	367.73	340.25	404.1
September	608.40	605.67	622.08	575.59	683.6
October	300.29	298.94	307.03	284.09	337.4
November	73.25	72.92	74.89	69.30	82.3
December	34.62	34.47	35.40	32.75	38.9
January	43.34	25.43	26.12	24.17	48.7
Total % of rainfall	3857.90 89.2%	3831.95 88.6%	3935.75 91.0%	3641.65 84.2%	4325 100%

Descriptives

truf all

					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
1.00	12	320.7708	232.70131	67.17508	172.9195	468.6222	34.62	723.57
2.00	12	275.2333	230.41454	66.51495	128.8349	421.6317	25.43	720.32
3.00	12	318.8800	232.40379	67.08920	171.2177	466.5423	26.12	739.83
4.00	12	302.0692	222.02303	64.09253	161.0025	443.1359	24.17	684.56
Total	48	304.2383	222.74955	32.15113	239.5586	368.9181	24.17	739.83

1,2,3 and 4 represent almond, mango, pear and forest respectively

ANOVA

truf all

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	16004.367	3	5334.789	.101	.959
Within Groups	2316012	44	52636.627		
Total	2332016	47			

Appendix 5.100: Volume of Stemflow and incident rainfall in mm

Months	Almond	Mango	Pear	Rainforest	Incident rainfall
February	7.07	6.74	8.26	7.94	108.7
March	18.36	17.52	21.47	20.62	282.5
April	27.56	26.33	32.27	31.0	424.6
May	29.89	28.51	34.95	33.57	459.8
June	41.69	39.76	48.75	46.82	641.4
July	52.85	58.41	61.78	59.35	813.0
August	26.27	25.05	30.70	29.50	404.1
September	44.43	42.38	51.95	49.90	683.6
October	21.93	20.92	25.64	24.63	337.4
November	5.35	5.10	6.25	6.01	82.3
December	2.53	2.41	2.96	2.84	38.9
January	3.17	1.78	2.18	2.10	48.7
Total % of rainfall	281.13 6.5%	268.15 6.2%	328.70 7.6%	315.73 7.3%	4325 100%

Descriptives

stflow

					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
1.00	12	23.4250	16.99355	4.90561	12.6278	34.2222	2.53	52.85
2.00	12	22.9092	17.70797	5.11185	11.6581	34.1603	1.78	58.41
3.00	12	27.2633	20.03901	5.78476	14.5312	39.9955	2.18	61.78
4.00	12	26.1900	19.24769	5.55633	13.9606	38.4194	2.10	59.35
Total	48	24.9469	18.03001	2.60241	19.7115	30.1822	1.78	61.78

1,2,3 and 4 represent almond, mango, pear and forest respectively

ANOVA

stflow

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	160.556	3	53.519	.156	.925
Within Groups	15118.268	44	343.597		
Total	15278.825	47			

Appendix 6.1: Step-wise regression results for organic matter and plant biomass parameters in topsoil: Avocado pear

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.460[a]	.212	-.003	.75600	.212	.984	3	11	.436
2	.438[b]	.192	.057	.73285	-.020	.276	1	11	.610
3	.423[c]	.179	.116	.70971	-.013	.192	1	12	.669
4	.000[d]	.000	.000	.75469	-.179	2.831	1	13	.116

a. Predictors: (Constant), crowncover, treeheight, diameter

b. Predictors: (Constant), crowncover, treeheight

c. Predictors: (Constant), treeheight

d. Predictor: (constant)

ANOVA[e]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.687	3	.562	.984	.436[a]
	Residual	6.287	11	.572		
	Total	7.974	14			
2	Regression	1.529	2	.764	1.423	.279[b]
	Residual	6.445	12	.537		
	Total	7.974	14			
3	Regression	1.426	1	1.426	2.831	.116[c]
	Residual	6.548	13	.504		
	Total	7.974	14			
4	Regression	.000	0	.000	.	.[d]
	Residual	7.974	14	.570		
	Total	7.974	14			

a. Predictors: (Constant), crowncover, treeheight, diameter

b. Predictors: (Constant), crowncover, treeheight

c. Predictors: (Constant), treeheight

d. Predictor: (constant)

e. Dependent Variable: organicmatter

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	-2.906	7.215		-.403	.695			
	treeheight	.674	.632	.358	1.066	.309	.423	.306	.285
	diameter	2.512	4.781	.220	.525	.610	.284	.156	.141
	crowncover	-.019	.029	-.231	-.657	.525	.010	-.194	-.176
2	(Constant)	-5.108	5.692		-.897	.387			
	treeheight	.858	.509	.456	1.687	.117	.423	.438	.438
	crowncover	-.010	.023	-.119	-.438	.669	.010	-.126	-.114
3	(Constant)	-5.199	5.509		-.944	.362			
	treeheight	.796	.473	.423	1.682	.116	.423	.423	.423
4	(Constant)	4.064	.195		20.856	.000			

a. Dependent Variable: organicmatter

Appendix 6.2: Step-wise regression results for organic matter and plant biomass parameters in topsoil: Mango

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.398[a]	.158	-.071	.50246	.158	.689	3	11	.577
2	.390[b]	.152	.011	.48274	-.006	.077	1	11	.787
3	.326[c]	.106	.037	.47629	-.046	.655	1	12	.434
4	.000[d]	.000	.000	.48545	-.106	1.543	1	13	.236

a. Predictors: (Constant), crowncover, diameter, treeheight

b. Predictors: (Constant), crowncover, treeheight

c. Predictors: (Constant), treeheight

d. Predictor: (constant)

ANOVA[e]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.522	3	.174	.689	.577[a]
	Residual	2.777	11	.252		
	Total	3.299	14			
2	Regression	.503	2	.251	1.079	.371[b]
	Residual	2.796	12	.233		
	Total	3.299	14			
3	Regression	.350	1	.350	1.543	.236[c]
	Residual	2.949	13	.227		
	Total	3.299	14			
4	Regression	.000	0	.000	.	.[d]
	Residual	3.299	14	.236		
	Total	3.299	14			

a. Predictors: (Constant), crowncover, diameter, treeheight

b. Predictors: (Constant), crowncover, treeheight

c. Predictors: (Constant), treeheight

d. Predictor: (constant)

e. Dependent Variable: organicmatter

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	4.050	2.332		1.737	.110			
	treeheight	.267	.205	.591	1.301	.220	.326	.365	.360
	diameter	-.466	1.683	-.081	-.277	.787	-.068	-.083	-.077
	crowncover	-.016	.024	-.316	-.673	.515	.126	-.199	-.186
2	(Constant)	3.919	2.194		1.787	.099			
	treeheight	.272	.196	.603	1.390	.190	.326	.372	.370
	crowncover	-.018	.022	-.351	-.809	.434	.126	-.227	-.215
3	(Constant)	2.951	1.814		1.627	.128			
	treeheight	.147	.118	.326	1.242	.236	.326	.326	.326
4	(Constant)	5.200	.125		41.487	.000			

a. Dependent Variable: organicmatter

Appendix 6.3: Step-wise regression results for organic matter and plant biomass parameters in topsoil: Indian almond

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.263[a]	.069	-.185	.33277	.069	.272	3	11	.844
2	.258[b]	.067	-.089	.31901	-.002	.028	1	11	.870
3	.189[c]	.036	-.038	.31153	-.031	.398	1	12	.540
4	.000[d]	.000	.000	.30571	-.036	.481	1	13	.500

a. Predictors: (Constant), crowncover, diameter, treeheight

b. Predictors: (Constant), crowncover, treeheight

c. Predictors: (Constant), crowncover

d. Predictor: (constant)

ANOVA[e]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.090	3	.030	.272	.844[a]
	Residual	1.218	11	.111		
	Total	1.308	14			
2	Regression	.087	2	.044	.428	.661[b]
	Residual	1.221	12	.102		
	Total	1.308	14			
3	Regression	.047	1	.047	.481	.500[c]
	Residual	1.262	13	.097		
	Total	1.308	14			
4	Regression	.000	0	.000	.	.[d]
	Residual	1.308	14	.093		
	Total	1.308	14			

a. Predictors: (Constant), crowncover, diameter, treeheight

b. Predictors: (Constant), crowncover, treeheight

c. Predictors: (Constant), crowncover

d. Predictor: (constant)

e. Dependent Variable: organicmatter

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	6.844	2.123		3.223	.008			
	treeheight	.116	.185	.626	.627	.543	-.127	.186	.183
	diameter	.304	1.810	.051	.168	.870	-.020	.051	.049
	crowncover	-.026	.033	-.790	-.788	.447	-.189	-.231	-.229
2	(Constant)	6.865	2.032		3.378	.005			
	treeheight	.107	.170	.578	.631	.540	-.127	.179	.176
	crowncover	-.024	.030	-.740	-.807	.435	-.189	-.227	-.225
3	(Constant)	5.882	1.273		4.619	.000			
	crowncover	-.006	.009	-.189	-.694	.500	-.189	-.189	-.189
4	(Constant)	5.000	.079		63.345	.000			

a. Dependent Variable: organicmatter

Appendix 6.4: Step-wise regression results for organic matter and plant biomass parameters in topsoil: Adjoining rainforest

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.209[a]	.044	-.116	.61882	.044	.274	2	12	.765
2	.205[b]	.042	-.032	.59503	-.002	.020	1	12	.891
3	.000[c]	.000	.000	.58586	-.042	.572	1	13	.463

a. Predictors: (Constant), diameter, treeheight

b. Predictors: (Constant), diameter

c. Predictor: (constant)

ANOVA[d]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.210	2	.105	.274	.765[a]
	Residual	4.595	12	.383		
	Total	4.805	14			
2	Regression	.202	1	.202	.572	.463[b]
	Residual	4.603	13	.354		
	Total	4.805	14			
3	Regression	.000	0	.000	.	.[c]
	Residual	4.805	14	.343		
	Total	4.805	14			

a. Predictors: (Constant), diameter, treeheight

b. Predictors: (Constant), diameter

c. Predictor: (constant)

d. Dependent Variable: organicmatter

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	5.653	8.572		.659	.522			
	treeheight	.034	.240	.040	.140	.891	.069	.040	.040
	diameter	-1.553	2.221	-.200	-.699	.498	-.205	-.198	-.197
2	(Constant)	6.850	.709		9.668	.000			
	diameter	-1.598	2.113	-.205	-.756	.463	-.205	-.205	-.205
3	(Constant)	6.327	.151		41.828	.000			

a. Dependent Variable: organicmatter

Appendix 6.5: Step-wise regression results for organic matter and plant biomass parameters in subsoil: Avocado pear

Model Summary^d

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.535^a	.286	.092	.29260	.286	1.472	3	11	.276
2	.519^b	.270	.148	.28344	-.017	.260	1	11	.620
3	.490^c	.240	.181	.27782	-.030	.490	1	12	.497

a. Predictors: (Constant), crowncover, treeheight, diameter

b. Predictors: (Constant), crowncover, diameter

c. Predictors: (Constant), crowncover

d. Dependent Variable: organicmatter

ANOVA^d

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.378	3	.126	1.472	.276^a
	Residual	.942	11	.086		
	Total	1.320	14			
2	Regression	.356	2	.178	2.214	.152^b
	Residual	.964	12	.080		
	Total	1.320	14			
3	Regression	.316	1	.316	4.100	.064^c
	Residual	1.003	13	.077		
	Total	1.320	14			

a. Predictors: (Constant), crowncover, treeheight, diameter

b. Predictors: (Constant), crowncover, diameter

c. Predictors: (Constant), crowncover

d. Dependent Variable: organicmatter

Coefficients^a

		Unstandardized Coefficients		Standardized Coefficients			Correlations		
Model		B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part
1	(Constant)	.927	2.792		.332	.746			
	treeheight	.125	.245	.163	.510	.620	-.126	.152	.130
	diameter	-1.568	1.850	-.337	-.847	.415	-.445	-.248	-.216
	crowncover	-.011	.011	-.321	-.961	.357	-.490	-.278	-.245
2	(Constant)	2.301	.715		3.220	.007			
	diameter	-1.042	1.489	-.224	-.700	.497	-.445	-.198	-.173
	crowncover	-.012	.011	-.347	-1.085	.299	-.490	-.299	-.268
3	(Constant)	2.402	.686		3.500	.004			
	crowncover	-.017	.008	-.490	-2.025	.064	-.490	-.490	-.490

a. Dependent Variable: organicmatter

Appendix 6.6: Step-wise regression results for organic matter and plant biomass parameters in subsoil: Mango

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.406[a]	.165	-.063	.39544	.165	.724	3	11	.559
2	.381[b]	.145	.002	.38308	-.020	.261	1	11	.619
3	.294[c]	.086	.016	.38044	-.059	.821	1	12	.383
4	.000[d]	.000	.000	.38355	-.086	1.231	1	13	.287

a. Predictors: (Constant), crowncover, diameter, treeheight

b. Predictors: (Constant), diameter, treeheight

c. Predictors: (Constant), diameter

d. Predictor: (constant)

ANOVA[e]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.339	3	.113	.724	.559[a]
	Residual	1.720	11	.156		
	Total	2.060	14			
2	Regression	.299	2	.149	1.017	.391[b]
	Residual	1.761	12	.147		
	Total	2.060	14			
3	Regression	.178	1	.178	1.231	.287[c]
	Residual	1.882	13	.145		
	Total	2.060	14			
4	Regression	.000	0	.000	.	.[d]
	Residual	2.060	14	.147		
	Total	2.060	14			

a. Predictors: (Constant), crowncover, diameter, treeheight

b. Predictors: (Constant), diameter, treeheight

c. Predictors: (Constant), diameter

d. Predictor: (constant)

e. Dependent Variable: organicmatter

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	2.244	1.835		1.223	.247			
	treeheight	.153	.161	.428	.946	.365	.182	.274	.261
	diameter	-1.364	1.325	-.300	-1.030	.325	-.294	-.296	-.284
	crowncover	-.010	.019	-.239	-.511	.619	.005	-.152	-.141
2	(Constant)	1.813	1.579		1.148	.273			
	treeheight	.088	.097	.246	.906	.383	.182	.253	.242
	diameter	-1.548	1.235	-.341	-1.253	.234	-.294	-.340	-.334
3	(Constant)	3.006	.867		3.466	.004			
	diameter	-1.336	1.204	-.294	-1.109	.287	-.294	-.294	-.294
4	(Constant)	2.050	.099		20.700	.000			

a. Dependent Variable: organicmatter

Appendix 6.7: Step-wise regression results for organic matter and plant biomass parameters in subsoil: Indian almond

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.230[a]	.053	-.206	.27642	.053	.204	3	11	.892
2	.225[b]	.051	-.108	.26494	-.002	.024	1	11	.879
3	.220[c]	.048	-.025	.25486	-.002	.029	1	12	.867
4	.000[d]	.000	.000	.25174	-.048	.660	1	13	.431

a. Predictors: (Constant), crowncover, diameter, treeheight

b. Predictors: (Constant), crowncover, treeheight

c. Predictors: (Constant), treeheight

d. Predictor: (constant)

ANOVA[e]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.047	3	.016	.204	.892[a]
	Residual	.840	11	.076		
	Total	.887	14			
2	Regression	.045	2	.022	.320	.732[b]
	Residual	.842	12	.070		
	Total	.887	14			
3	Regression	.043	1	.043	.660	.431[c]
	Residual	.844	13	.065		
	Total	.887	14			
4	Regression	.000	0	.000	.	.[d]
	Residual	.887	14	.063		
	Total	.887	14			

a. Predictors: (Constant), crowncover, diameter, treeheight

b. Predictors: (Constant), crowncover, treeheight

c. Predictors: (Constant), treeheight

d. Predictor: (constant)

e. Dependent Variable: organicmatter

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	2.177	1.764		1.234	.243			
	treeheight	-.064	.154	-.416	-.413	.688	-.220	-.123	-.121
	diameter	-.234	1.503	-.048	-.155	.879	-.029	-.047	-.046
	crowncover	.005	.027	.205	.203	.843	-.195	.061	.060
2	(Constant)	2.161	1.688		1.281	.225			
	treeheight	-.057	.141	-.371	-.401	.696	-.220	-.115	-.113
	crowncover	.004	.025	.158	.171	.867	-.195	.049	.048
3	(Constant)	2.429	.615		3.948	.002			
	treeheight	-.034	.041	-.220	-.812	.431	-.220	-.220	-.220
4	(Constant)	1.932	.065		29.723	.000			

a. Dependent Variable: organicmatter

Appendix 6.8: Step-wise regression results for organic matter and plant biomass parameters in subsoil: Adjoining rainforest

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.276[a]	.076	-.078	.66905	.076	.494	2	12	.622
2	.273[b]	.074	.003	.64336	-.002	.021	1	12	.888
3	.000[c]	.000	.000	.64441	-.074	1.046	1	13	.325

a. Predictors: (Constant), diameter, treeheight

b. Predictors: (Constant), diameter

c. Predictor: (constant)

ANOVA[d]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.442	2	.221	.494	.622[a]
	Residual	5.372	12	.448		
	Total	5.814	14			
2	Regression	.433	1	.433	1.046	.325[b]
	Residual	5.381	13	.414		
	Total	5.814	14			
3	Regression	.000	0	.000	.	.[c]
	Residual	5.814	14	.415		
	Total	5.814	14			

a. Predictors: (Constant), diameter, treeheight

b. Predictors: (Constant), diameter

c. Predictor: (constant)

d. Dependent Variable: organicmatter

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	4.984	9.268		.538	.601			
	treeheight	-.038	.260	-.040	-.144	.888	.000	-.042	-.040
	diameter	-2.386	2.401	-.279	-.994	.340	-.273	-.276	-.276
2	(Constant)	3.651	.766		4.765	.000			
	diameter	-2.336	2.285	-.273	-1.023	.325	-.273	-.273	-.273
3	(Constant)	2.886	.166		17.345	.000			

a. Dependent Variable: organicmatter