Integrated Agroforestry for Sustainable Development in Small Inland Valleys in Ghana

ガーナの内陸小低地集水域の持続可能な開発のための総合アグロフォレストリ

Ph. D.

Ebenezer OWUSU-SEKYERE

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Ebenezer OWUSU-SEKYERE

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ABSTRACT

It was as far back as the 1930s that F. Hardy working in Trinidad recognized the existence of a nearly closed nutrient cycle between a mature forest and the soil underneath. Basing arguments on this phenomenon, Hirose and Wakatsuki, (1997) hypothesized that lowland areas in inland valleys can be fertilized sufficiently for sustainable "Sawah" rice production if there is bush mature forest growth upland. Nonetheless, because of the pressure on the land, there has been a rapid total conversion of primary forest into scrub, farm-bush and secondary forest. As a result, there are more secondary than primary forests in most tropical countries. The Dwinyan watershed is characterized by primary forest, a reserved area that protects the catchments of the watershed from which many rivers take their source, secondary forest and cultivated areas in the uplands. The secondary forest had been put to mono-cropping and/or mixed food cropping systems and allowed to fallow for long periods. The cultivated areas are cocoa plantations, citrus plantation, mixed crop farms and young herbaceous and/or shrubby fallow. In each of the land uses, there is potential nutrient flow from the soil through the plant roots systems to the leaves. The nutrients recycling within the land use ecosystems of different types of vegetation compositions in the uplands may leach down along the toposequence to influence the lowlands for rice-based cropping systems. Therefore, there is urgent need to investigate the floristic compositions of the various land uses, quantify nutrients being cycled in the primary forest, secondary forest or cocoa plantations and assess nutrients releases and fluxes to the soil and determine whether or not the structure of the tree canopies and crowns complexities could be related to the pattern in stand stature and the trees characteristics could be evaluated for agroforestry farming systems in Ghana. Mean annual leaf litter produced by the primary and secondary forests was both 7.9 t ha^{-1} and that for cocoa plantation was 6.9 t ha^{-1}. The primary forest leaf litter showed rapid decomposition than the secondary forest and the cocoa leaf litter. Nutrients released from the decomposing leaf litters were fast for N, P, K, Ca and Mg for the primary and secondary forests. High leaf litter fall occurred when rainfall was low. Decomposition of leaf litter was independent of the pattern of monthly rainfall. Weight loss of the leaf litter was attributed to the nature or characteristics of the leaf litter, concentrations of total phenols and the fine 2.0 mm mesh used for litter boxes. At $t_{1/2}$, decomposition of the selected mixed species leaves litter was relatively faster followed by mixture of total leaves, Accumulation of nitrogen occurred in all the litter types and was highest for the total mixed species leaves (TM). Phosphorus was released gradually whilst potassium was very rapid during the first two months of exposure. Subsequently, partial accumulation of magnesium and calcium elements was observed. Mineralization of P, K, Mg and Ca followed the pattern of the disappearance of the litter. Polyphenols appeared to have influenced decomposition and nutrient releases from the litter types more than the characteristic of the leaf litter types. Decomposition pattern of leaf litter did not show clear relation to the monthly rainfall. Mean annual N fluxes from the decomposed leaf litter to the soil estimated for the secondary forests were 170 for Akyaakrom secondary forest (AS) and 226 kg ha^{-1} for Dopiri secondary forest (DS). Mean annual P fluxes were 5.3 and 5.2 kg ha^{-1} in AS and DS, respectively. Annual fluxes of Ca were 114 and 142 kg ha^{-1} in AS and DS, whilst Mg were 18 and 39 kg ha^{-1}, respectively. The peak monthly fluxes of all the nutrients were mostly observed during March to June overlapping with the rainy season. Monthly fluctuations of N fluxes were more pronounced. Nutrient imbalances of P and Ca fluxes from decomposed leaf litter in the secondary forests suggested their scarcities. The distribution of major mineral elements in the leaves showed mean concentrations in decreasing order of K > Ca > Mg > P > N in AS and Ca > K > Mg > P > N for DS. The bark samples showed concentrations in decreasing order of Ca > K > Mg > N > P in both forests. Generally, concentrations of Ca in the tree species bark samples of the two secondary forests were about three times higher than they were in the leaves. The land quality indexes of the principal nutrients N, P, K, Ca and Mg were higher in AS than in DS. The soil under the land uses (i.e. primary, secondary forests and cocoa plantation) revealed that cocoa plantation was higher in Ca than in the secondary and primary forests soils. The primary forest recorded higher top soil N, P, K, and Mg nutrient contents due to non-frequent removal of the vegetation, presence of organic matter that increases soil carbon content and cation exchange capacity. Generally, trends of nutrients released and the quantities of nutrient fluxes estimate in the land uses in Ghana suggested that nutrient cycling was better in the primary forest followed by the secondary forest and cocoa plantation was the least. Farmers preserve trees that have different uses and crown forms for different crop plants associations on their farms. This study was related the physiognomy of the forest canopy to the pattern in stand stature and trees characteristics for potential agroforestry systems in Ghana. The trees species with extensive crowns were emergents whose crowns were fully exposed from above and occupied the A-layer of the canopy. The tree species with relatively smaller crowns, partially exposed and fully overshadowed were the lower storied trees. All the tree species guilds were found in all the layers. Populations of the pioneer tree species (P) guild was low (8.7%), non-pioneer light demanders (NPLD) was 49.1% and shade-bearers (NPSH) was 42.2%. Out of a total of 436 tree species encountered, diversity of P was 22% whilst NPLD was 42% and NPSH was 36%. The

indigenous tree species have the potential to be domesticated and accepted for local agroforestry systems combinations. This will lead to rapid response for integration of indigenous tree species into farmlands rather than the introduction of 'alien tree species'.

若月ら(1998)は、成熟した森林が集水域に十分な面積で分布していれば、集水域の低地部分には持続可能な「水田」米作を実施するに十分な地質学的、地形学的および水分学的施肥プロセス（地質学的施肥）が存在可能であるとの仮説を提案した。

しかしながら、増大する人口圧のために、一次林はやぶ、農業用低木および二次林へと、大規模で急速な変化が進んできた。集水域の高地部分の多様な植生からなる生態系を循環する栄養分は、トポシーケンスに沿って流下し、低地での米作を基本とする作物システムに影響する可能性がある。生物多様性に関する森林伐採の衝撃の程度は、環境条件と森林のタイプに関係する。ガーナの森林移行帯集水域においては、一次林、二次林およびココアプランテーション等、森林利用全体において、人為的森林劣化と自然的劣化が継続している。

それ故、集水域における持続可能なアグロフォレストリー（混農林業）の実践と低地の管理手法を確定するために、集水域における様々な土地利用を評価し、一次林、二次林およびココアプランテーションにおいて循環する栄養分を定量して、土壌に放出される栄養分を評価することが緊急に必要である。

DWINYAN 集水域における土地利用ごとに生育している樹種の無機成分について

ガーナの一次林である Tinte-Bepo Forest Reserve は 1949 年に初めて設立され、現在 1986 年の森林保護法のもとに保護されている。一次林(Tinte-Bepo Forest Reserve)、二次林(Akyaakrom、 28 years old) および (Dopiri、 27 years old)、2 つのココアプランテーション (Dopiri および Gold Valley)は Dwinyan 集水域に存在する。Dwinyan 川はこの 2 つのココアプランテーションを分けている。

一次林、Akyaakrom および Dopiri 二次林、およびココア林で、DBH が 5.0cm 以上の樹木についてそれぞれ、150、100 および 50 樹種の樹皮と葉のサンプルを収集した。一次林、Akyaakrom および Dopiri 二次林でそれぞれ、26、20 および 18 の異なる樹種の科が識別された。樹木数は Tinte-Bepo 一次林、Akyaakrom および Dopiri 二次林のそれぞれのプロットで、0.45 ha 中 435、および 0.19 ha 中 158 と 118 であった。樹木密度と構成では、一次林が 1 番高く、次いで Akyaakrom、Dopiri の順であった。

一次林の樹種の葉は、高濃度の K、 Ca、 Si、 Mg、 S、 Al および P を含むが、Na、 Mn および Fe の濃度は低かった。樹種の葉の Cu、 Mo、 Sr および Zn 含有量は痕跡程度であった。Akyaakrom 二次林において、葉のサンプル中の元素濃度は K > Ca > Si > S > Mg > P > Al > Na > Fe > Sr > Mn > Mo > Cu > Zn (表 1)の順であった。概して Akyaakrom の樹種の樹皮元素濃度は葉よりも低く、原生林の葉と樹皮の養分濃度よりも低かった。

Dopiri 二次林の生きている葉の養分濃度は平均して Ca > K > Si > Mg > S > P > Na > Al > Fe > Mn > Sr > Mo > Zn > Cu の順であった（表1）。Dopiri 二次林の樹皮の養分の濃度は Ca > K > Si >S > Mg > Al > Na > P > Sr > Fe > Mn > Mo > Cu > Zn の順であった。２つのココアプランテーションより採取した葉と樹皮は Cu の濃度が比較的高かったが、Mn、Mo、Si、Sr 、Zn の濃度は低かった。ココアの葉と樹皮の Ca の濃度は 2 つのココアプランテーションで高かった。一次林の葉の養分濃度は二次林およびココアプランテーションのサンプルと高い正の相関が見られた。

DWINYAN 集水域における一次林、二次林、ココアプランテーション内の葉のリター分解による養分放出について

リターは植物の成長に必要な多くの量の養分を含んでいる(Songwe *et al.*、 1995)。土壌や林床の微生物相や動物相はリターを分解し無機化する(Swift *et al.*、 1979)。葉のリターの分解速度は他のリター部分より早く、葉の無機化は早いと思われる。全ての森林で（ココアプランテーションは 1 地域のみ）毎月採取し乾燥した葉のリターを樹木の同定に用いた。それぞれの森林において 2 年間の毎月のリター生産量の平均を用いて年間の葉のリター生産量を推定した。

分解と養分放出の測定は 4 回行い、一次林の樹種の落ちた新鮮な葉を用いた。2 つの相違な二次林に２つの観察セットを設け、様々な樹種より落ちた新鮮な葉の分解と養分放出を観察した。年平均の葉のリター量は初年度 TB で 8.5 t ha^{-1} 、AS で 9.1 t ha^{-1} 、DS で 8.9 t ha^{-1} 、DC で 7.1 t ha^{-1} 、GVC で 6.7 t ha^{-1} であり、その間の降水量は

1400 mm であった。Dwinyan 集水域において、葉のリター量は土地の利用の違いによる差は見られなかった。

一次林、二次林、ココアプランテーションの葉のリターは乾期に最も多く、それは森林のタイプ間では有意な差が見られなかった（$P < 0.05$）。大雨期に落葉のリター量は乾期の次に多くなり、原生林と二次林の間で違いは見られなかったが、森林とココアプランテーションの間では違いが見られた。小雨期で落葉のリター量は最低となり、森林タイプ間で違いは見られなかった。しかしながら、季節と土地利用ごとの葉のリター生産の間で大きな違いが見られた。全ての森林タイプで落葉のリター量は正の相関が見られた。逆に落葉のリター量と雨量は負の相関が見られた。しかし、落葉のリター量は年間降水量と相関が見られた

葉のリターの分解と月毎の降水量との間には直接の関連は見出されなかった。年間を通じて葉のリターはゆっくりと、しかし、段階的に分裂と分解が進んでいった。Akyaakrom (AM)と Dopiri (DM)の二次林間で 1 月、3 月、9 月そして 10 月において混ざった葉のリターの分解は大きく異なっていた。2 つのココアプランテーションの葉のリターの分解は良く似た傾向を示した。Dopiri ココアプランテーションの葉のリター分解は Gold Valley のものより相対的に遅かった。

それぞれの葉のリターより抽出したポリフェノールの総量によりリターのタイプ間での分解率の違いを良く説明できた。AG において早くポリフェノールが低下した葉のリターは早く分解し、AM や DA において遅くポリフェノールが低下した葉のリターは分解が遅かった。ココアプランテーションにおいてポリフェノール以外の要因

がポリフェノールより大きくココアの葉のリター分解に関係したと思われた。

全ての葉のリターは一般に分解が進む事によって養分を放出する。葉のリターからの K、Mg 、P 養分放出は分解の過程でリターのタイプ間で有意な差は見られなかった。リターの葉の分解の初期の段階で養分放出率は乾燥質量の減少率より早かった。他の葉のリターでも同じ傾向が見られた。

一般に、養分濃度は葉のリターの分解に沿ってゆっくり減少する。マメ科の樹木 *G. simpliciffolia* (AG)は他の樹木の葉のリターより分解と養分の放出は早かった。2 つの二次林からの混ざった葉のリターは養分放出が遅かった。Gold Valley のココアプランテーションの葉のリターからの K と Mg の放出は分解過程でなくなってしまった。一般に、ココアの葉の分解は比較的遅いとされている。

月ごとの養分の流れ（循環量）はリター生産量とリター中の養分残在量から推定された。一次林における年間の養分流量は Ca で 157 kg ha^{-1} yr^{-1} 、N で 166 kg ha^{-1} y^{-1}、K で 32 kg ha^{-1} y^{-1} 、Mg で 23 kg ha^{-1} y^{-1}、 P で最も少なく 7 kg ha^{-1} y^{-1} であった。N の養分の流れで脱窒による減少は計算しなかったが、Tinte-Bepo 保全林の原生林で富んだ養分の流れは貧栄養の土壌を維持している事が示されている (Annan-Afful、 *et al.*、 2001)。

同様に、二次林の養分の流れは AS と DS においてそれぞれ、 N で 172 と 236 kg ha^{-1}、Ca で 119 と 149 kg ha^{-1}、 Mg で 42 と 19 kg ha^{-1}、K で 44 と 13 kg ha^{-1}、そして P で 6 と 5 kg ha^{-1} であった。DC と GVC ココアプランテーションの養分の流れはそれぞれ N で 104 と

111 kg ha^{-1}、P で 6.7 と 2.5 kg ha^{-1}、 K で 16 と 7 kg ha^{-1}、Ca で 95 と 110 kg ha^{-1}、Mg で 7 と 3 kg ha^{-1} であった。森林とココアプランテーションにおける葉のリター生産の違い、葉の特徴由来する分解の傾向と養分の放出パターンは、それぞれのサイトにおける養分の流れのパターンの総量の違いより導かれた。

集水域総合アグロフォレストリーによる持続的な水田耕作システムについて

森林の樹冠要素は光合成組織を含む。樹木は地下の生態系より養分を吸い上げる。加えて、樹木のリターは林床へ有機物を供給し分解によるエネルギーサイクルへ原料を加えることに貢献する(Parker、1994)。樹木はまた、農業生産の持続に重要な役割を示している。適正なアグロフォレストリーシステムは土壌の物理性を向上させ、土壌の有機物を持続させ養分循環を増進させる(Sanchez、 1987)。

ガーナでは、伝統的な稲作が実施されてきた。生物多様性の崩壊はガーナの森林政策のガイドラインによる森林保全の方向性を見直すことを必要とした。水田耕作技術を完全にするための森林は、種の多様性、土地利用間での著しい物質と養分フラックスを定量的に評価する事が必要で、コミュニティーの参加による荒廃した土地への植林、そしてガーナの新しい森林政策のフレームワークによって、コミュニティーメンバーが多様な収入源を確保できるような方策を促進しなくてはならない.

CHAPTER 1

INTRODUCTION

1.1 General Introduction

It was as far back as the 1930s that F. Hardy working in Trinidad recognized the existence of a nearly closed nutrient cycle between a mature forest and the soil underneath (Hardy, 1936). Wakatsuki *et al*, (1998), basing arguments on phenomenon described by Hardy, (1936) hypothesized that lowland areas in inland valleys can be fertilized sufficiently for sustainable "Sawah" rice production if there is a bush mature forest growth upland. Nonetheless, because of the pressure on the land, there has been a rapid total conversion of primary forest into scrub, farm-bush and secondary forest (Longman and Jenik, 1987). As a result, there are more secondary than primary forests in most tropical countries (Gomez-Pompa and Vazquez-Yanes, 1974).

This study was conducted under the project which had already selected Dwinyan watershed as one of the benchmark sites. This benchmark site was particularly selected among the rest of others because the preferred study sites for the study were available i.e. forest reserve, secondary forest and the cocoa plantations. Dwinyan watershed is characterized by various land uses in the uplands (Fig. 1). The primary forest (forest reserve), protects the catchments of the watershed from which many rivers take their source. The other land uses are the secondary forests and cultivated areas. The secondary forests were as the result of long period of fallow. The cultivated areas are cocoa plantations, citrus plantation, mixed crop farms and young herbaceous and/or shrubby fallow creating shortage of arable land in the area. The rather recent farms (1-3 years old) are relatively younger than the cocoa plantations (l0 years old) as compared to secondary forests (more than 20 years old). In each of the land uses, there is potential nutrient flow from the soil through the plant roots systems to the leaves. The nutrients recycling within the land use ecosystems of different types of vegetation compositions in the uplands may leach down along the toposequence to influence the lowlands for rice-based cropping systems. Therefore, there is urgent need to investigate the floristic compositions of the various land uses, quantify nutrients being cycled in them and assess nutrients releases to the soil surfaces so as to undertake sustainable agroforestry intervention practices and make management decisions for lowland cropping systems.

1.2 Tropical semi-deciduous primary forest (Tinte-Bepo Forest Reserve)

Tinte-Bepo Forest Reserve is between latitudes 6^{o} 33'N and 7^{o} 03'N and between longitudes 1^{o} 55'W and 2^{o} 06'W (Fig. 2). The total area of the reserve is 11, 554 ha and the eastern block selected for this study covers 2,935 ha. It belongs to the dry tropical semi-deciduous forest (Hall and Swaine, 1976). Previous exploitations of timber resource and annual bush fires have disturbed the forest. However, the present state of the forest is described as reasonably healthy as a primary forest.

Tropical rain forests are well known for their large number of tree species, their multilayered canopy structure and the mosaic of forest patches at different phases of their growth cycle (Whitmore, 1990). The number of biological species is estimated to form 50% of species in the world (Yamada, 1992). The tropical forests are in fact believed to be biotic museums.

1.3 Secondary forests

Tropical forests are vulnerable to degradation by human activities. Wherever detailed analyses are made in the tropics, the vegetation is found to be the product of past disturbance by people or by natural events such as fire, wind, flood or biotic outbreak (Brown and Lugo, 1990, Brown *et al*, 1991 and Whitmore, 1991). Two secondary forests, Akyaakrom and Dopiri in Dwinyan Watershed (Fig. 2) were selected for this study. They were 28 and 27 years old, respectively.

The reconstituting woody vegetation is derived from clearing as a result of shifting cultivation and had been allowed to fallow. Akyaakrom secondary forest (AS) covers 30 ha, located 0.8 km south of the primary forest and the dominant tree species is *Griffornia simplicifolia*. Dopiri secondary forest (DS) covers 20 ha, located 7 km south of the primary forest and dominated by *Albizia zygia* tree species. The reconstituted vegetation in both secondary forests represents mosaics of various plant successional stages. Even though the secondary forests are allowed to fallow, timber harvesting and firewood gathering activities still persist.

1.4 Tree species diversity in the forests of Dwinyan Watershed

The impact of deforestation on biodiversity is a function of environment and the forest type. Areas of homogeneous environment tend to be less affected than areas of great environmental complexity (Kangas, 1990). The biodiversity of ecosystems is actually believed to be dependent on natural disturbance (Leigh, 1990). However, limits are imposed on the types of species that can grow on sites where people create conditions that are more stressful than those that occur after natural catastrophes (Janzen, 1990). A different species will benefit from the change in condition at the expense of the one that holds temporal dominance over the site. Such changes in species composition are inevitable and as reported by Howe, (1990) that seedlings usually exhibit poor survival near their parents, but do so much better when growing far away from them.

In the land uses, i.e. primary and secondary forests and the cocoa plantations, there have been and continue to be under the influences of anthropogenic and natural disturbances. The natural disturbances cannot be eliminated but human activities such as timber harvesting, farming, wood and other forest products gathering could be minimized in these ecosystems. It is established that there is usually a large decrease in the contents of organic matter and nitrogen in the topsoil, accompanied by high rates of release of nitrates following clearing and burning. The contents of organic matter and nitrogen rise again during the woody fallow. The amounts of available phosphorus and bases in the soil fall during cropping and are restored to a degree during fallow.

1.5 Cocoa Plantations

Theobroma cacao (cocoa) is an evergreen simple cauliflorous perennial cash-tree-crop that can survive for more than 50 years in a plantation. Buds on the stem and branches as well as on the twigs remain active for an indefinite period. From the physiological point of view of evergreen trees, food materials are stored in trunks and large branches as may be necessary for the growth of the flowers and fruits (Haberlandt, (1926), Klebbs, 1911 quoted by Richards, (1996). Two cocoa plantations, Dopiri and Gold Valley (Fig. 2) were selected for the study. They are pure plantations devoid of shade trees species.

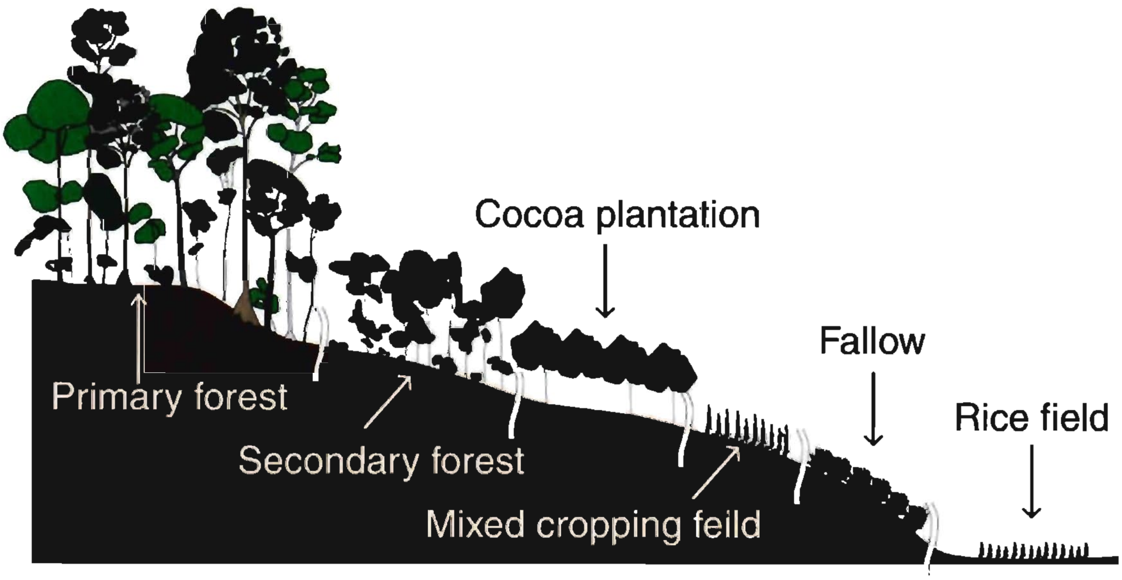


Figure 1: Schematic map showing the land uses of Dwinyan watershed.

1.6 Rice-based cropping systems in Dwinyan inland valley.

Dwinyan Watershed has small inland valleys where rice, maize and vegetables are cultivated annually. Dry season farming is also practiced. The tropical African soils are much older and more strongly leached and therefore deficient in mineral nutrients. Rice cultivation in Ghana has largely been the traditional upland type. The vegetations of the uplands are destroyed through slash-and-burn and shifting cultivation. The yields of the upland rice have been less than 1.6 t ha^{-1}. Until recently, lowland agriculture, i.e. inland valleys was used for mainly vegetable cultivation.

Inland valleys and hydromorphic fringes in Ghana suitable for rice-based cropping systems are estimated to cover about one million hectares. The numerous small inland valleys found scattered across the country offer the best condition to support rice cultivation. The "Sawah" is rice-based cultivation system in the lowlands without sacrificing the upland resources but restoring the lost upland forests. It is a sustainable strategy for better utilization of inland valley ecosystems. The vegetation cover in the uplands would improve soil quality leading to geological fertilization of the lowlands as hypothesized by Hirose and Wakatsuki, (1997).

1.7 Objectives

1. Determine the mineral element compositions in live tree species leaves and bark of the land uses
2. Assess nutrient status and nutrient releases during decomposition and mineralization from leaf litters of tree species of the land uses and
3. Determine whether or not the structure of the forest canopy and crowns complexities could be related to trees characteristics for agroforestry farming systems in Ghana.

Chapter 2

MINERAL ELEMENTS COMPOSITION IN LIVING TREES SPECIES OF THE LAND USES IN DWINYAN WATERSHED

2.1 Introduction

Tinte-Bepo Forest Reserve, a primary forest in Ghana was first constituted in 1949 and now protected under the Forest Protection Law of 1986 (Annan-Afful *et al* 2004). Previous timber exploitation in the reserve was controlled by selection system of harvesting. The reserve is located in the dry semi-deciduous forest zone (Hall and Swaine, 1976). In lowland forests, the number of tree species greater than or equal to 10 cm diameter at breast height (dbh) is between 60-150 ha^{-1} and in rich areas it can exceed 200 or 300 ha^{-1} (Huston, 1994 and Richards, 1996).

The diversity of tree species is very high in tropical rain forests. The major factor for the structure of the tree communities is the distribution, characteristics of mineral elements in both trees and soils. Pringle, (1990) reported on the relationships between the environment heterogeneity and the coexistence of tree species. The recent rapid population growth has reduced fertile agricultural lands considerably and primary forestlands are under constant pressure for agricultural activities. Farms are established through traditional methods of slash-and-burn and shifting cultivation. The farms are abandoned after 2-3 years continuous cropping i.e. when soil fertility decline and search for new fertile land. Thus, primary vegetation species are being removed and converted into fallow lands at faster rates.

The establishments of cocoa plantations follow the farming systems in Ghana i.e. slash and burn and mulching but more sedentary than shifting farmlands, except during expansion of existing farms. The decline of productivity of cocoa farms in Ghana is largely attributed to the scarcity of labour for maintenance, expansion and aging of the farms. However, tree nutrition, decomposition of ground litter, nutrient release and mineralization in established plantations have received very little or no attention. In this chapter, mineral elements in the tree species leaves and bark of the primary forest, secondary forests and cocoa plantations were evaluated to determine the elemental requirements of the tree species in each land use.

Tree species require specific mineral element and in specific quantity for growth, reproduction and survival in an ecosystem. The nutrition and nutrient flow in the tree species in the land uses along the toposequence (lowland to upland) will offer guidelines for better prescriptions of agroforestry intervention for sustainable lowland farming system. The information generated on nutrient dynamics may be useful for the different tree species associations, combinations and integration in agroforestry for sustainable and increased productivity in Ghana.

Objective

The objective of this study is to determine the mineral element compositions in live tree species of the primary forest, reconstituting secondary forests and the cocoa plantations that characterized the Dwinyan watershed.

2.2 Material and Method

The Study Area (Dwinyan Watershed)

Primary forest (Tinte-Bepo Forest Reserve), secondary forests (Akyaakrom, 28 years old) and (Dopiri, 27 years old), and two cocoa plantations (Dopiri and Gold Valley) land uses characterized the Dwinyan Watershed (Fig. 1). They were located on both the same latitudes (6^{o} 33' N and 7^{o} 03' N) and longitudes (1^{o} 55 and 2^{o} 06 W) (Fig. 2). Tinte-Bepo Forest Reserve had mean elevation of 366 m. Akyaakrom secondary forest with mean slope of 5^{o} and 200 m mean elevation was 0.8 km south of the primary forest. It covered 30 ha and the dominant tree species was *Griffornia simplicifolia* (Atoto). Dopiri secondary forest, 300 m mean elevation covered 20 ha and was 7.0 km south of the primary forest and with mean slope of 9^{o}

(Fig.2). The dominant tree species in Dopiri secondary forest was *Albizia zygia* (Okro). The Dopiri cocoa plantation, 300 m above mean sea level was 0.5 ha and 2 km from the Dwinyan River. Gold Valley cocoa plantation with the elevation of 200 m and was 20 m from the river. The Dwinyan River separated the two cocoa plantations. These land uses were selected for this study.

The soil in the primary forest was Ferric Acrisol (Bekwai series) and that of both secondary forests was Ferric Lixisol but Bekwai and Nzima series for Akyaakrom and Dopiri, respectively. The soil in the Dopiri cocoa plantation was Ferric Lixisol (Nzima series) and Gold Valley was Ferric Luvisol (Kokofu series). The pH was 5-7 for all the soil types, slightly acidic (Wakatsuki *et al.*, 2001).

Floristic composition

Total inventory was conducted on a 0.5 ha plot in the primary forest (Fig. 3). Three 0.19 ha plots were established in each secondary forests and inventoried (Figs. 4 and 5). Enumeration was conducted by using the quadrat sampling method. The entire plot of each land use was subdivided into 10m x 10m quadrat sampling plots. In each quadrat, total enumeration was conducted on all tree species greater than 4.0 cm diameter at breast height (dbh). All the tree species within the diameter range set were tagged with identification numbers. The tree species were identified by the local names and scientific names were matched with literature provided by Irvine, (1961) and Hawthorne, (1990).

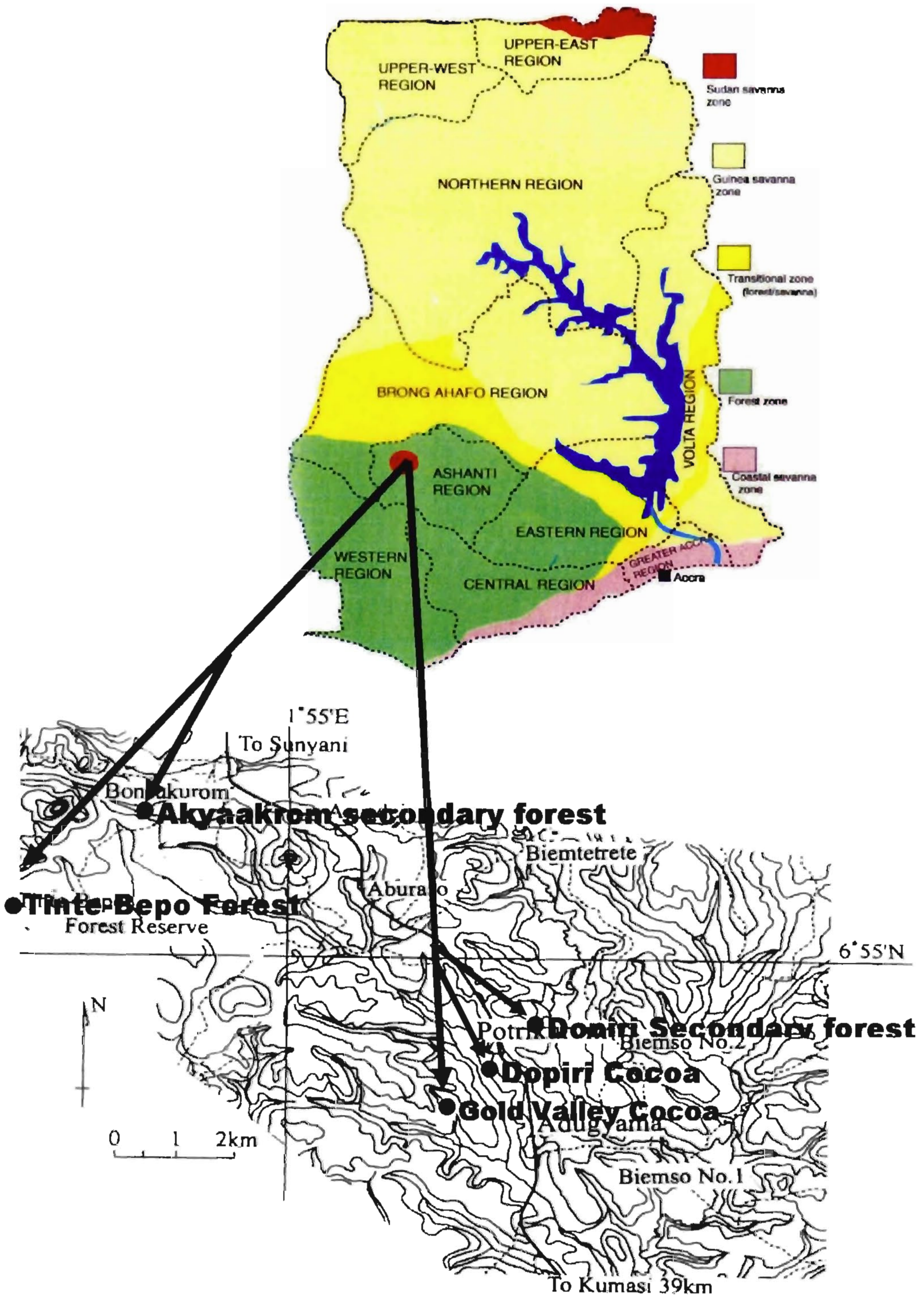


Figure 2: Map of Ghana showing the locations of Dwinyan Watershed, the primary, secondary forests and cocoa plantations.

Tree Leaves and Bark samples collection

Fresh (green) leaf samples were collected from the trees above 5.0 cm dbh, chopped and oven-dried at 60°C for 72 hours. Bark samples were taken (at breast height) from all trees whose leaves samples were collected, cleaned, chopped and oven-dried at 60°C for 72 hours and stored for nutrient analysis in the laboratory. The bark and leaves samples were collected on 160 tree species from the primary forest, 118 from Akyaakrom secondary forest, 88 from Dopiri secondary forest and 50 cocoa tree species in the plantations over 5.0 cm dbh in each land use. Collection of the samples was limited to tree species whose leaves and bark samples were both taken in the forests. However, random samples were collected from the cocoa trees in the two plantations

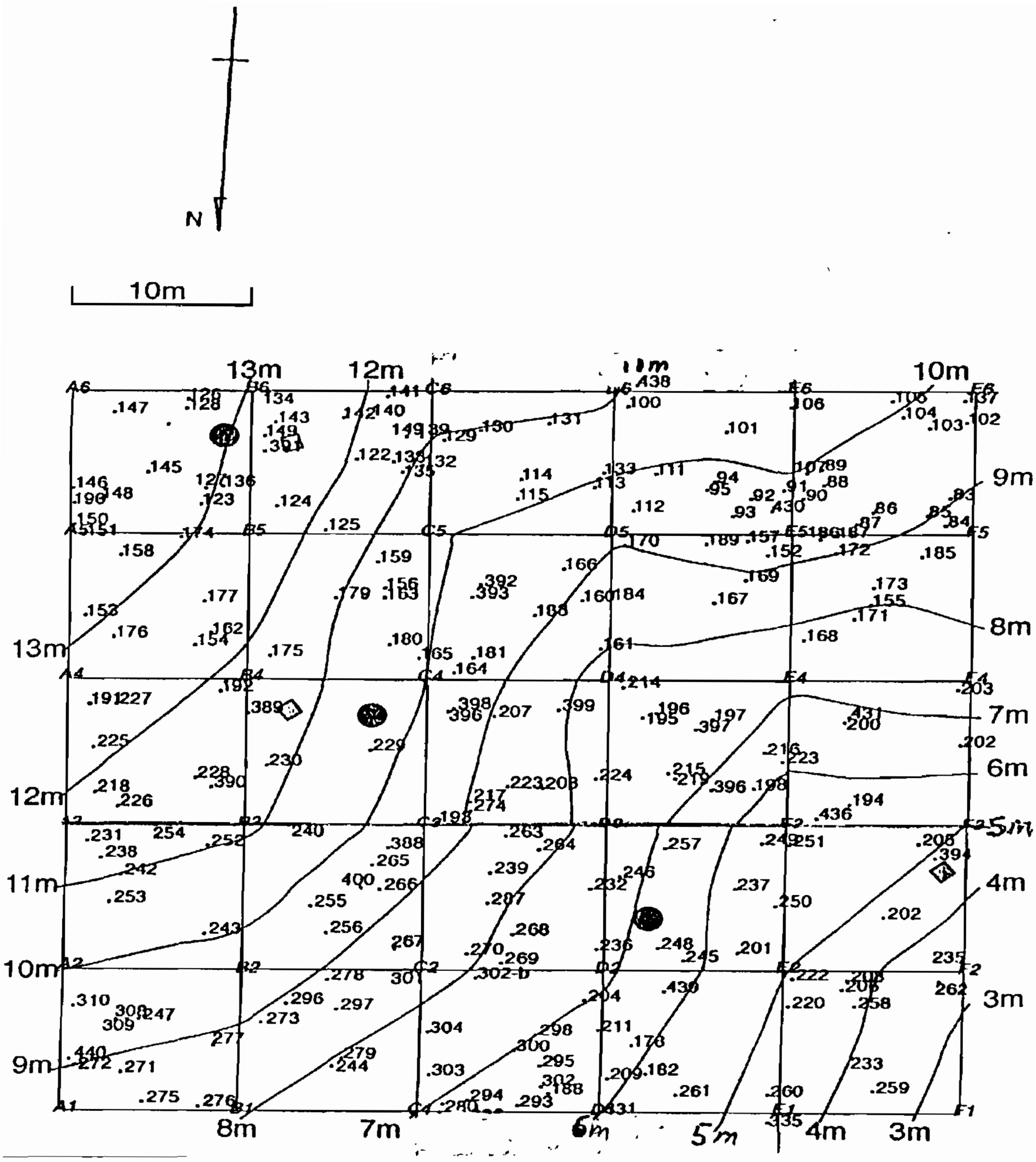


Figure 3: Topographic and tree species locations map of the sampled study plot and the positions of litter traps in the primary forest.

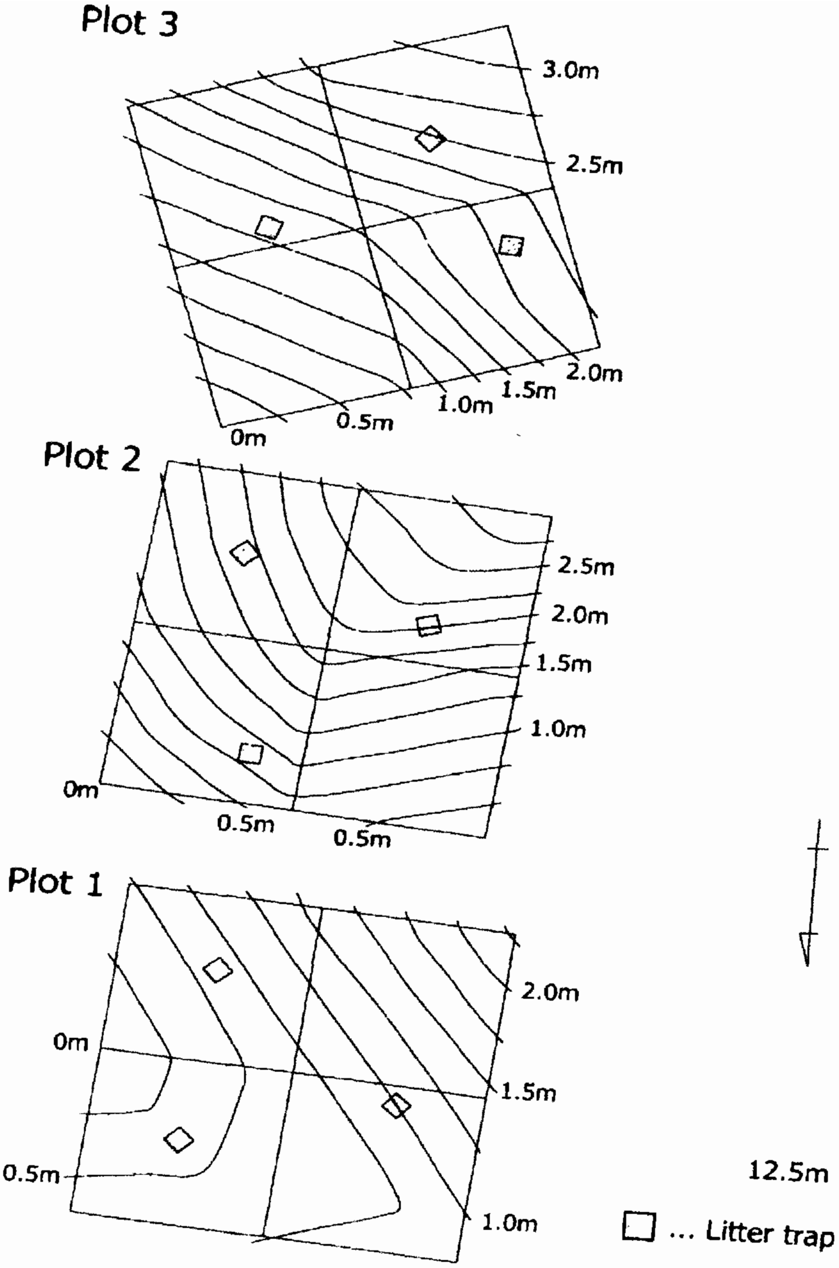


Figure 4: Topographic map showing the positions of the litter traps in Akyaakrom Secondary forest plots

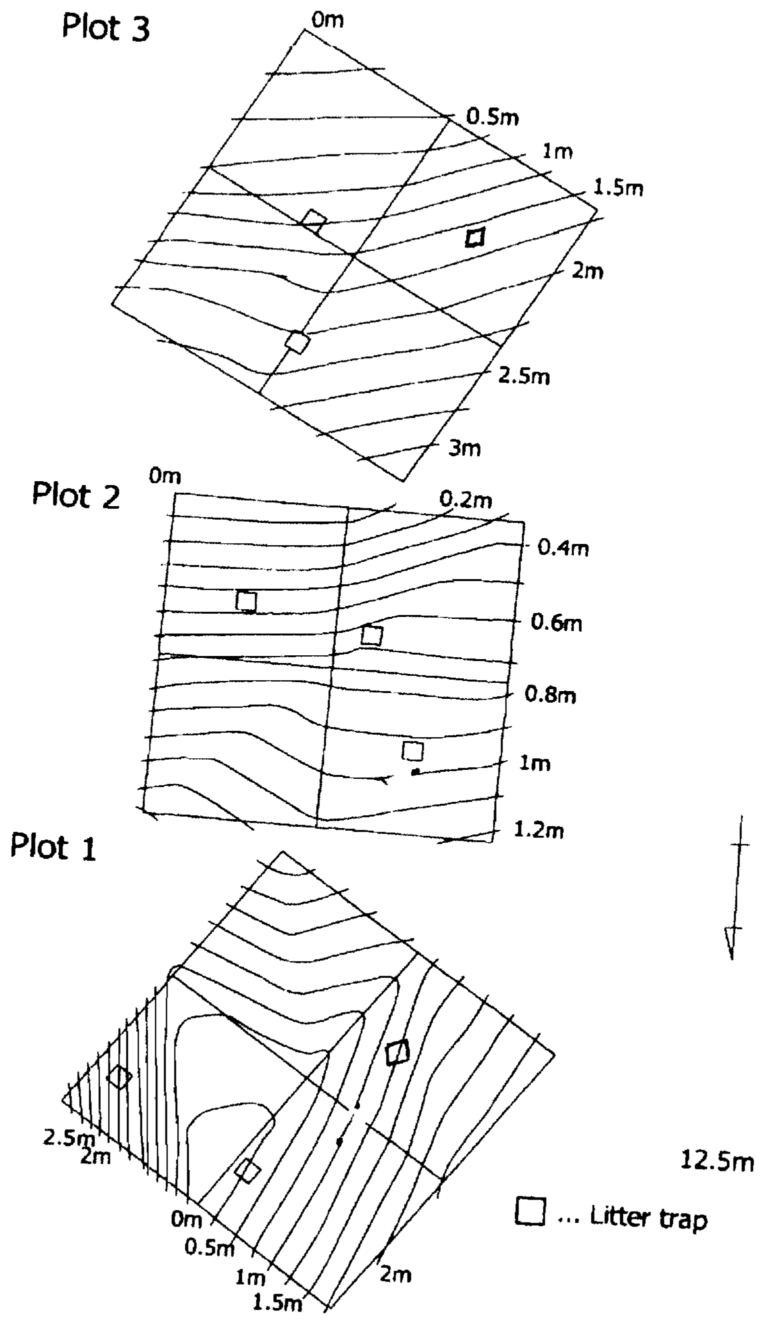


Figure 5: Topographic map showing the positions of the litter traps in Dopiri Secondary forest plots

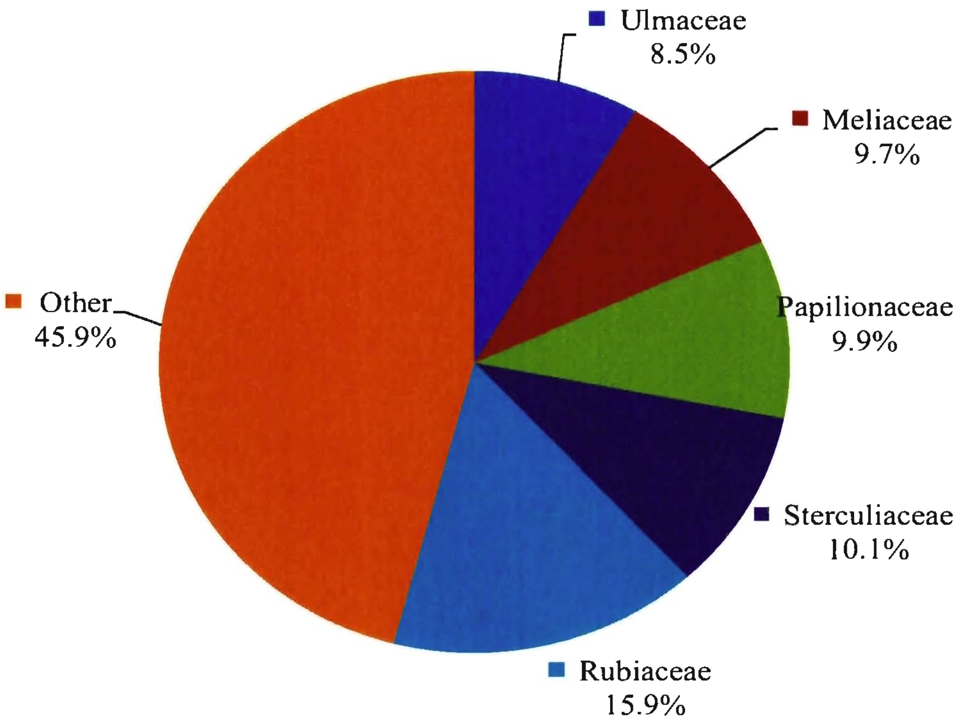
Laboratory analyses

The samples were milled using a vibrating mixer mill. The concentrations of Na and K were determined by atomic absorption spectrometry (AAS 170-70) after digestions by the wet oxidation (HNO_3) method under pressure (Teflon container placed in the oven at 150°C for 4 hours). The other elements concentrations were determined using the inductively coupled plasma spectrometer (ICPS-2000) after the digestion.

2.3 Results and Discussions

Plant diversity

The vegetation composition in the primary forest (Tinte-Bepo Forest Reserve) was high dominated by rubiaceae (15.9%), sterculiaceae (10.1%), papilionaceae (9.9%), meliaceae (9.7%) and ulmaceae (8.6%). The legume tree species, papilionaceae (9.9%), caesalpiniaceae (4.8%), sapindaceae (2.8%) and mimosaceae (2.1%) populations were low in the primary and constituted 19.6% of the total species (Fig. 6).



<u>Others</u> (45.9%)

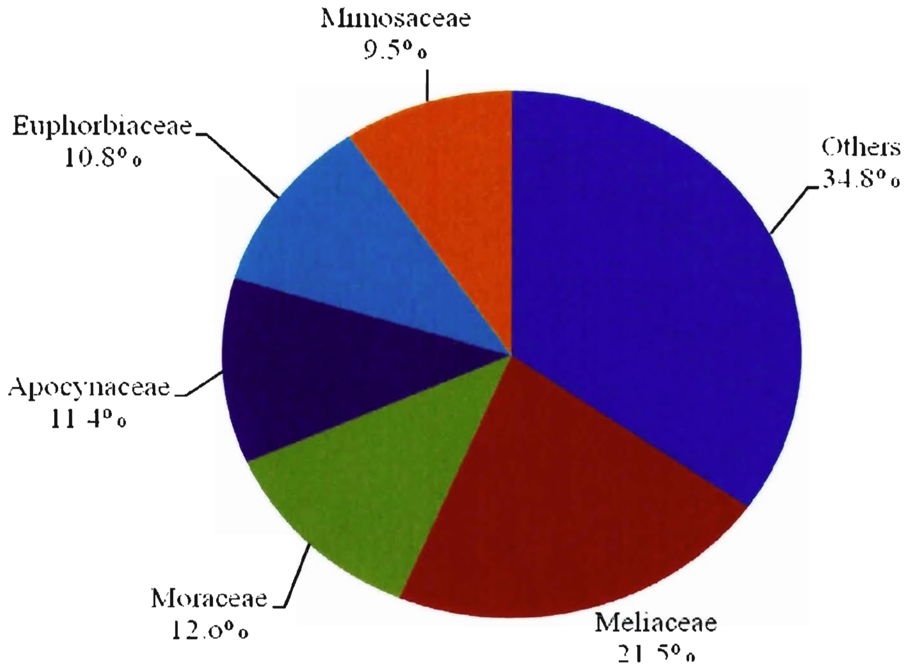
Pandaceae	5.5%	Annonaceae	5.5%	Caesalpiniaceae	4.8%
Apocynaceae	4.8%	Euphorbiaceae	4.6%	Melastomataceae	3.7%
Sapindaceae	2.8%	Loganiaceae	2.5%	Guttiferae	2.1%
Mimosaceae	2.1%	Lecythidaceae	1.6%	Moraceae	1.4%
Sapotaceae	1.4%	Olacaceae	1.1%	Flacourtiaceae	0.5%
Bombaceae	0.5%	Irvingiaceae	0.2%	Ebenaceae	0.2%
Combretaceae	0.2%	Burseraceae	0.2%	Anacardiaceae	0.2%

Figure 6: Top 5 dominant tree families and others in the Tinte-Bepo primary forest Reserve.

Results from the inventory indicated that meliaceae tree species family constituting 21% dominated in Akyaakrom secondary forest followed by moraceae (12%), apocynaceae (11.4%), euphorbiaceae (10.8%), mimosaceae (9.5%) and others were sterculiaceae, ulmaceae, sapindaceae, papilionaceae, myristicaceae, caesalpiniaceae, combretaceae, tiliaceae, simaroubaceae, bombaceae, anacardiaceae, rutaceae, rubiaceae, rhamnaceae and olacaceae and constituted 34.8% (Fig.7).

In Dopiri secondary forest, the most dominant tree species were the families of moraceae (18.6%), mimosaceae (17.8%), euphorbiaceae (14.4%), meliaceae (9.3%) and rubiaceae (8.5%). The other families comprised of papilionaceae, apocynaceae, sterculiaceae, connaraceae, sapindaceae, lauraceae, combretaceae, bombaceae, bignoniaceae, ulmaceae, annonaceae and anacardiaceae constituted 31.4% (Figure 8).

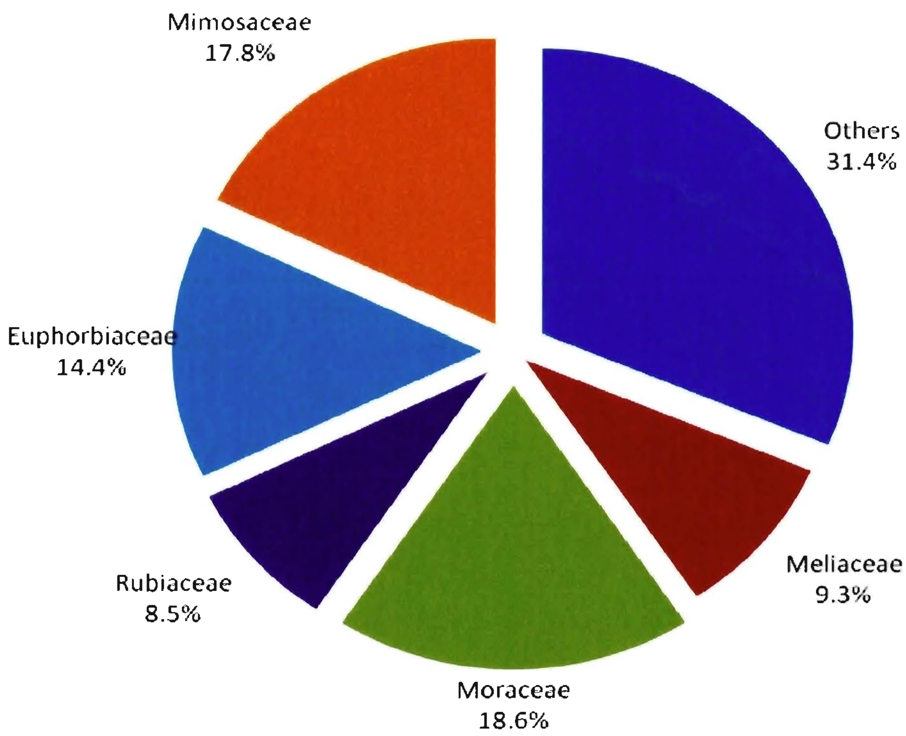
There were 26, 20 and 18 different tree species families identified in primary forest, Akyaakrom and Dopiri secondary forests, respectively. Tree populations were 435 in the 0.5 ha plot in the primary forest, 158 and 118 in 0.19 ha plots in Akyaakrom and Dopiri secondary forests, respectively. In terms of tree density and composition, primary forest was higher than Akyaakrom that was superior to Dopiri secondary forest.



<u>Others</u> (34.8 %)

Sterculiaceae	6.9%	Ulmaceae	4.4%	Sapindaceae	3.2%
Papilionaceae	3.2%	Myristicaceae	3.2%	Caesalpiniaceae	2.5%
Combretaceae	1.9%	Tiliaceae	1.3%	Simaroubaceae	1.3%
Bombaceae	1.3%	Anacardiaceae	1.3%	Rutaceae	0.6%
Rubiaceae	0.6%	Rhamnaceae	0.6%	Olacaceae	0.6%

Figure 7: Top 5 dominant tree families and others in Akyaakrom secondary forest (AS)



<u>Others</u> (31.4%)

Papilionaceae	5.9%	Apocynaceae	5.1%	Sterculiaceae	3.4%
Connaraceae	3.4%	Sapindaceae	2.5%	Lauraceae	1.7%
Combretaceae	1.7%	Bombaceae	1.7%	Bignoniaceae	1.7%
Ulmaceae	0.8%	Annonaceae	0.8%	Anacardiaceae	0.8%

Figure 8: Top 5 dominant tree species families and others in Dopiri secondary forest (DS)

Nutrient element compositions in live trees of the land uses

Primary forest tree species leaves contained high concentrations of K, Ca, Si, Mg, S, Al and P but lower in Na, Mn and Fe. Their leaves contained only trace quantities of Cu, Mo, Sr and Zn (0.02-0.05 g kg^{-1}) (Table 1). The mean values indicated that K concentration (11 g kg^{-1}) was the highest whilst Cu and Zn (0.02 g kg^{-1}) were the lowest in fresh leaves of the primary forest trees species. The trend was K > Ca > Si > Mg > S > Al > P > Na > Mn > Fe > Sr > Mo > Zn and Cu in descending order. Very high variability existed in Ca concentration (97 %) whilst S, Al, Cu, Mn, Sr and Zn variations in the leaves ranged between (40-54 %). Mean values of the bark samples showed different order of element concentrations from that of the leaves i.e. S > Al > K > Mg > Ca > P > Fe > Mn > Si > Mo > Na > Sr > Zn and Cu in descending order. Variability was high in S, Cu, Fe, Mn, P and Zn (102 %-72 %). Variations in the other elements were low and ranged between 20-49 %.

In Akyaakrom secondary forest, the elements in the leaves showed concentrations in decreasing order of K > Ca > Si > S > Mg > P > Al > Na > Fe > Sr > Mn > Mo > Cu > Zn (Table 1). The concentrations of K, Ca, P, ranged from 13.0- 1.3 g kg^{-1} and 7.8 – 0.3 g kg^{-1} for Si, Mo, Sr and Zn. Concentrations of these elements were high in Akyaakrom tree species leaves as compared to the leaves from the primary forest. The arithmetic means of their bark element concentrations indicated that Ca > K > Si > S > Mg > Al > P> Na > Sr > Fe > Mn > Mo > Cu > Zn in decreasing order. The concentrations of the microelements of Mo, Sr and Cu showed high variability in the leaves (86-98 %) and in the bark, Sr and Cu variations were high (134 and 65 %, respectively) (Table 1).

Table 1: Total nutrient element concentrations (g kg^{-1}) in leaves and bark of live trees species in the land uses

Site and Sample		Elements concentration (g kg^{-1})													
		Na	K	S	Al	Ca	Cu	Fe	Mg	Mn	Mo	P	Si	Sr	Zn
	Mean	0.635	11.062	2.557	1.724	9.901	0.017	0.243	3.673	0.554	0.047	1.027	6.123	0.087	0.019
	Sd.	0.127	3.334	0.601	2.061	2.307	0.008	0.046	1.191	0.214	0.013	0.184	2.898	0.038	0.010
TB Leaves	Min.	0.426	6.138	1.607	0.394	6.102	0.009	0.194	1.894	0.335	0.028	0.623	3.670	0.028	0.009
	Max.	0.990	18.927	4.225	8.376	14.107	0.046	0.384	7.616	1.131	0.070	1.384	16.447	0.175	0.049
	C.V.	0.200	0.330	0.400	0.390	0.970	0.470	0.190	0.040	0.390	0.280	0.180	0.640	0.440	0.540
	Mean	0.401	4.422	9.945	5.370	2.219	0.223	1.115	3.320	1.100	0.070	1.180	0.584	0.336	0.224
	Sd.	0.175	1.347	10.176	2.993	4.445	0.169	0.839	1.481	0.840	0.017	0.845	0.159	0.164	0.168
TB Bark	Min.	0.052	1.295	0.107	0.703	11.989	0.016	0.084	1.065	0.008	0.012	0.120	0.000	0.086	0.006
	Max.	0.848	6.523	34.017	12.970	33.233	0.646	3.213	6.860	3.191	0.085	3.303	0.747	0.729	0.645
	C.V.	0.436	0.304	1.023	0.557	0.200	0.758	0.753	0.446	0.763	0.244	0.716	0.273	0.487	0.753
	Mean	0.693	13.368	2.404	1.230	12.290	0.031	0.306	2.145	0.132	0.106	1.343	7.847	0.165	0.026
	Sd.	0.106	5.163	0.697	0.729	5.569	0.031	0.112	1.111	0.113	0.315	1.035	3.841	0.387	0.015
AS Leaves	Min.	0.480	6.921	1.203	0.387	2.733	0.002	0.143	0.105	0.000	0.010	0.287	4.648	0.025	0.009
	Max.	0.904	24.479	3.988	3.620	26.500	0.106	0.496	3.636	0.455	1.367	4.192	21.304	1.709	0.057
	C.V.	0.152	0.386	0.290	0.590	0.453	0.972	0.365	0.518	0.856	2.977	0.771	0.489	2.344	0.567

Site and Sample		Elements concentration (g kg^{-1})													
		Na	K	S	Al	Ca	Cu	Fe	Mg	Mn	Mo	P	Si	Sr	Zn
AS Bark	Mean	0.355	9.090	2.256	1.324	33.565	0.032	0.164	1.717	0.121	0.070	0.421	2.990	0.283	0.021
	S.d	0.073	3.412	0.751	0.359	13.145	0.021	0.029	0.903	0.041	0.030	0.137	1.560	0.381	0.010
	Min.	0.278	1.799	0.479	0.573	6.939	0.008	0.102	0.299	0.007	0.031	0.294	0.007	0.034	0.001
	Max.	0.572	15.910	3.533	2.228	63.924	0.095	0.214	4.113	0.209	0.141	0.795	8.413	1.768	0.040
	C.V.	0.205	0.375	0.333	0.271	0.392	0.646	0.175	0.526	0.338	0.425	0.325	0.522	1.343	0.485
DS Leaves	Mean	0.904	14.665	2.122	0.902	10.776	0.001	0.358	2.557	0.214	0.056	1.222	8.631	0.072	0.028
	S.d	0.171	3.620	0.593	0.346	5.625	0.000	0.089	0.802	0.236	0.060	0.403	2.498	0.037	0.038
	Min.	0.732	10.592	1.215	0.412	1.134	0.000	0.175	1.094	0.023	0.022	0.382	6.118	0.000	0.000
	Max.	1.238	20.943	3.974	1.693	22.236	0.022	0.518	4.071	0.812	0.268	1.754	15.166	0.121	0.168
	C.V.	0.189	0.247	0.280	0.384	0.522	0.590	0.250	0.313	1.104	1.067	0.330	0.289	0.518	1.350
DS Bark	Mean	0.533	9.789	2.252	1.315	30.131	0.018	0.187	1.355	0.094	0.039	0.431	4.626	0.251	0.001
	Sd.	0.235	6.100	1.019	0.972	17.012	0.002	0.346	1.077	0.061	0.016	0.162	3.126	0.327	0.001
	Min.	0.197	2.915	0.211	0.081	1.983	0.001	0.078	0.087	0.024	0.000	0.063	0.172	0.025	0.000
	Max.	1.372	35.926	5.426	6.364	73.763	0.038	3.531	7.503	0.433	0.092	1.242	23.002	2.690	0.060
	C.V.	0.440	0.623	0.452	0.739	0.565	0.290	1.849	0.794	0.642	0.408	0.375	0.676	1.307	0.750
DC Leaves		0.630	15.240	1.200	0.309	18.740	0.170	0.410	0.100	0.010	0.003	0.250	0.147	0.090	0.002
DC Bark		0.750	3.850	1.630	0.362	42.860	0.130	0.270	0.350	0.001	0.002	0.420	0.410	0.170	0.005
GVC Leaves		0.800	18.500	1.330	0.259	19.850	0.250	1.090	0.220	0.010	0.004	0.240	0.114	0.080	0.002
GVC Bark		0.640	17.630	2.180	0.170	3.480	0.210	0.270	0.004	0.080	0.129	2.100	0.045	0.005	0.000

Generally, Akyaakrom tree species bark elements concentrations were lower than they were in their leaves and in both leaves and bark of the primary forest tree species. Live tree species leaves from Dopiri secondary forest analyzed indicated that the mean concentrations were in the descending order of Ca > K > Si > Mg > S > P > Na > Al > Fe > Mn > Sr > Mo > Zn > Cu (Table 1). Analysis result of tree bark samples from Dopiri secondary forest showed that the element concentrations in decreasing order was Ca > K > Si >S > Mg > Al > Na > P > Sr > Fe > Mn > Mo > Cu > Zn. The coefficient of variation was highest for Fe, Sr, Al, Mg, Si, K, Mn and Zn and ranged between 62- 185 %. Variations in concentrations of Na, S, Ca, P, Cu and Mo within the tree species were small.

The analysis of the cocoa leaves and barks samples from the two cocoa plantations revealed relatively higher concentrations of Cu but lower concentrations of Mn, Mo, Si, Sr and Zn (Table 1). The concentration of Ca in the cocoa leaves and bark were higher in both plantations. However, K and Ca were very low in the bark of cocoa trees from Dopiri and Gold Valley plantations (3.85 and 3.48 g kg^{-1}, respectively) (Table 1).

These elements are required in different concentrations and at different parts of the tree species for different functions. Masunaga, (1998) reported that several tree groups exist in terms of elemental requirement levels and some tree species tend to accumulate specific elements. The element concentration correlation matrix in the land uses presented in Table 2 showed that tree species from each site positively correlated with one another.

Table 2: Correlation of element compositions in leaves (L) and barks (B) of live trees species in the primary (T), secondary (AS, DS) forests and Cocoa (DC, GVC) plantations land uses

	DS L	DS B	AS L	AS B	T B	T L	DC L	GVC L	DC B
DS B	0.732								
AS L	0.991	0.812							
AS B	0.681	0.997	0.767						
T B	0.222	0.125	0.234	0.119					
T L	0.983	0.794	0.989	0.752	0.307				
DC L	0.844	0.907	0.889	0.892	0.193	0.873			
GVC L	0.858	0.874	0.894	0.856	0.201	0.88	0.997		
DC B	0.534	0.966	0.636	0.982	0.052	0.616	0.809	0.763	
GVC B	0.779	0.381	0.738	0.339	0.313	0.735	0.719	0.767	0.181

14 observations were used in this computation.

The positive correlations obtained indicated that the concentrations of the elements were related and the differences were due to sites conditions. The leaves from the trees were closely positively correlated, r-values ranged between 0.844-0.997. Similarly, the bark concentrations, except TB and GVCB, were also closely correlated and r = 0.966-0.997. TB and TL were weakly correlated (r = 0.307), TB weakly but positively correlated with its leaves, leaves and barks of the secondary forests (AS L, AS B, DS L and DS B) and the cocoa leaves and barks from the two plantations (DC L, DC B, GVC L and GVC B). Conversely, the tree leaves from the primary forest (T L) showed high positive correlations with the lives tree samples from the secondary forests and the cocoa plantations (Table 2). The differences in mineral elements concentrations in live trees in the sites suggested that such differences might have been as a result of levels of the exchangeable Al and Ca in the different soil series in the ecosystems as reported by Masunaga *et al*, (1998).

Chapter 3

NUTRIENT RELEASE FROM DECOMPOSING LEAF LITTERS FROM THE PRIMARY FOREST, SECONDARY FORESTS and COCOA PLANTATIONS IN DWINYAN WATERSHED

3.1 Introduction

Litter contains considerable quantities of nutrients necessary for plant growth (Songwe *et al.*, 1995). Through the biological processes of plant nutrition, leaves play major roles in the manufacture of food. It is a vital tissue for plant growth and survival. Leaves fall to the forest floor and once on the ground, the leaf material begins to decompose in order to release the stored-up nutrients. Soil and forest floor micro-organisms and fauna break down and mineralize the litter (Swift *et al.*, 1979). The decomposer community, the physicochemical environment and the litter resource quality play a part to regulate the rate of decomposition (Anderson & Swift, 1983). . Most nutrients are lost from the ecosystem through erosion and leaching (both lateral and vertical) of upland soils (Radulovich and Sollins, 1991). During high water or floods, mineral elements (both in suspension and dissolved) contain in sediments and organic material from up-slope sources and are re-captured in lowland areas (Frangi and Lugo, 1985).

Plant materials with high nitrogen content such as legumes are considered to be of high resource quality to the decomposer community and thus decompose faster (Weeraratna, 1979, Swift *et al.*, 1979). However, Melillo *et al.*, (1982) observed that plant materials with high lignin content decompose more slowly. Swain, (1979) observed that polyphenolics could also retard decomposition by forming resistant complexes and inhibiting enzyme activity. Investigations into decomposition and mineralization in tropical forests have often been low because, the great heterogeneity of the ecosystem makes it difficult to select species to investigate for a meaningful approximation of the decomposition rates in a forest as a whole (Songwe *et al.* 1995). The contribution of leaves to total litter fall has been reported to be in the range of 80 to 86% (Klinge and Rodrigues, 1968) or 72% (Gong and Ong, 1983) in various tropical forests. Leaves decompose faster than the other litter types and leaf mineralization is supposed to be rapid. In this chapter, leaves were therefore considered for the decomposition and mineralization studies in a primary forest, two secondary forests and two cocoa plantations.

Objective

To assess nutrient status and releases from tree species decomposing leaf litters in the land uses.

3.2 Materials and Methods

Litter fall collection

Square wooden Litter traps frame measuring 1.0 m^2 (1.0 m x 1.0 m inner surface dimensions) were constructed. Nylon mesh (size 2 mm) was secured round the frame and allowed to sag beneath the frame but not touching the forest floor to collect the fallen litter. Each trap was set on peg supports 1.0 m above the forest floor. Nine traps were erected randomly in the primary, nine in each of the secondary forests and five in each of the cocoa plantations in September 1998 (Figs. 3, 4 and 5). The fallen litter in each trap was collected every 14 days from September 1998 till August 2000.

The leaf portion was sorted out from the total trapped litter, dried in an oven at 60°C for 72 hours, weighed and stored in a cool dry place. The dried leaf litter for each month was used to identify the tree species of the forests and only cocoa leaves were used in both plantations. Mean Monthly litter fall for the two years were used to estimate the annual leaf litter productions for each site. Mean monthly rainfall was monitored at Asuadei and Potrikrom towns (Fig. 2) for the two-year study period to fairly estimate the annual amount and distribution of precipitation for the entire watershed. Based on the distribution and the amount of precipitation for each month within the years, seasons were prescribed. Thus, dry season was from

November to February, major rainy season was from March to July and the minor rainy season, August to October in each year round (September 1998-August 1999 (year 1), and September 1999-August 2000 (year 2).

Field experiment of leaf litter decomposition

Four observations on decomposition and nutrient release were carried out from freshly fallen leaf litter of primary forest tree species. The fallen leaf litter was sorted out. The sorted leaves were grouped according to the species and the percentage contribution from each tree species to the total leaf litter (by weight) for each year was computed. The leaf litters of *Celtis* sp. (TC) (ulmaceae) and *Trichilia prieuriana* (TT) (meliaceae) that constituted more than 40% of the total leaf litter weight were each gathered into separate piles and subjected to decomposition separately. Other species i.e. *Baphia nitida* (papilionaceae), *Corynanthe pachyceras* (rubiaceae), *Ricinodendron heudelotii*, *Alchornea cordifolia* (euphorbiaceae) and *Ficus* sp. (moraceae) together representing about 20% of the total leaf litter were bulked together (selected species - TS), mixed proportionally and decomposed. Finally, a mixed-leaf litter (TM) containing leaves of all species trapped and in the proportions in which they were collected was also subjected to decomposition in the primary forest.

Two sets of observations carried out were on decomposition and nutrient release from fallen leaves from the various tree species in the two Akyaakrom (AS) and Dopiri (DS) secondary forests. The leaf litter of the legumes *G. simplicifolia* in AS (AG) and that of *A. zygia* in DS (DA) each represented more than 50% of the total leaves litter trapped was gathered together and subjected separately to the decomposition study at their respective sites. Mixtures of the leaf litters trapped were also subjected to decomposition study at each site i.e. Akyaakrom (AM) and Dopiri (DM) secondary forests. Each of these mixed leaf litters contained trapped leaves found at their respective sites in the proportions in which each was found. Only one treatment was carried out on each of the pure cocoa plantations leaf litters i.e. Dopiri (DC) and Gold Valley (GVC) (Fig 2).

Square decomposition boxes made of *Milicia excelsa* wooden frames and measuring 20 cm x 20 cm (surface inner dimensions) x 2 cm deep were constructed. Galvanized wire mesh (size 1.0 mm) was passed around to cover the top and bottom of the wooden frames to exclude larger decomposing organisms and minimize the loss of leaves after fragmentation. Ten grams of oven-dried leaves per observation was enclosed in each decomposition box and planted in the field in September 1998. There were 36 boxes for each treatment and fresh samples were kept for the initial chemical analysis.

Three 12 m x 12 m blocks were pegged out in each plot of the study sites and each block was subdivided into three quadrats (4 m x 4 m subplots). The ground was cleared of previously fallen litter to bring the decomposition boxes into direct contact with the soil. The decomposition boxes were randomly placed in each quadrat. For each observation, three (3) boxes were sampled, one box per block every 28 days beginning in October 1998.

The sampled boxes and the contents were taken to the laboratory and the partially decomposed leaf litters were carefully separated from the soil particles, plant roots and other materials. They were oven-dried at 60°C for 72 hours and weighed to determine their weight losses.

Laboratory analyses

The residual leaf litter samples from the three sampled boxes collected periodically for each observation were pooled together and milled using a vibrating mixer mill (MRK-Retsch, Mitamura Riken Kogyo). The nutrients were analyzed as described in chapter 2. Nitrogen (N) and carbon (C) concentrations were determined by dry combustion method (Sumigraph

N-C 90A Analyzer, Sumitomo Chemical). Total extractable phenols (TEPH) were determined using the acetone extraction method by Makker and Goodchild, (1996).

Data analyses

a). Nutrient release from leaf litters

Nutrient released from leaf litters were calculated by the following equation for each exposure month of decomposition:

$$NW_i = W \bullet C \quad (1)$$

Where NW is the nutrient amount in a residual leaf litter (mg) at the i^{th} exposure month. W is the dry mass/weight of residual leaf litter (g) and C is the nutrient element concentration in the residual leaf litter (mg g^{-1}) and started at the 0^{th} exposure month when the initial weight was 10g.

NW was calculated for each leaf litter type and for each nutrient element of K, Ca, Mg, P and N. Nutrient concentrations in leaf litters were not fully analyzed throughout the decomposition period because of limited quantities of residual samples for further chemical analyses at the later exposure months. However, the nutrient concentrations at the last analytical month were extrapolated to the later decomposition periods in order to estimate full nutrient release from all leaf litter types for the year. The amount of nutrient released was determined mainly on the dry mass weight of the remaining leaf litter, rather than by the nutrient concentration at later stages of decomposition. Rates of nutrient released from the leaf litters (Table 5) and the nutrient release model developed (Fig. 12) were assumed to be representative of all nutrients in the land uses and were applied to calculate nutrient release from leaf litters produced in each month.

b). Nutrient fluxes

Nutrient flux (kg ha^{-1} $month^{-1}$) from the leaf litters at each month was estimated by summing up the nutrient released from the leaf litters in each 12 consecutive months. It was calculated as follows:

$$NFx = \sum_{i=1}^{12} L(x-i) \bullet NRi \quad \text{.........(2)}$$

Where NFx is nutrient flux (kg ha^{-1} $month^{-1}$) at x^{th} month, $L(x-i)$ is leaf litter production (kg ha^{-1} $month^{-1}$) at the exposure month of x-i and NRi is the nutrient released rate (kg kg^{-1} leaf litter). The mean monthly litter productions for the 2-year study periods were used. Data gathered were analyzed using the StatView and SAS (1999) software.

3.3 Results and Discussions

Leaf litter fall productions

Fig. 9 shows the mean monthly leaf litter production and rainfall amount and distribution from September 1998 to August 2000 for the land uses in the watershed. Leaf litter production was highest in the dry season (November to February) in each year. The highest mean monthly leaf litter production was 174.9 g m^{-2} and least 62.5 g m^{-2} for AS and observed in January and December, respectively in the first year cycle (September 1998-August 1999). In the major rainy season, March to July, the highest and least leaf litter falls were observed in July (45.0 and 27.4 g m^{-2}) for TB and GVC, respectively. During the minor rainy season, August to September, in the first year, the highest leaf litter fall was in September (50.1 g m^{-2}) for DS and lowest (22.1 g m^{-2}) in August for TB (Fig. 9). During the second year round, the observed trends were similar to the previous year. Thus, the highest leaf litter fall was recorded in February as 151.0 g m^{-2} for GVC and least as 88.2 g m^{-2} in January for TB during the dry season. The major rainy season recorded as low as 27.4 g m^{-2} for GVC and 8.0 g m^{-2} for DS in July. The minor season recorded the lowest of 12.4 g m^{-2} and the higher of 39.9 g m^{-2} both in August for AS (Fig. 9).

The mean annual leaf litter falls were 8.5 t ha^{-1} for TB, 9.1 t ha^{-1} for AS and 8.9 t ha^{-1} for DS, 7.1 t ha^{-1} for DC and 6.7 t ha^{-1} for GVC during the first year period whilst total amount of rainfall recorded was 1400 mm. In the second year cycle, mean annual leaf litter falls were 7.4 t ha^{-1} for TB, 6.8 and 6.5 t ha^{-1} for AS and DS, respectively, 6.7 and 6.2 t ha^{-1} for DC and GVC, respectively when rainfall was 1600 mm. The leaf litter fall patterns were similar for both the first and the second years. However, mean annual leaf litter production was higher both in TB and AS than in DS, DC and GVC (7.9 t ha^{-1}, 7.7 t ha^{-1}, 6.9 and 6.5 t ha^{-1}, respectively). This could be accounted for by the higher tree species diversities in the Tinte-Bepo primary forest and Akyaakrom secondary forest. Tree diversities were low in the Dopiri secondary forest and the two cocoa mono-tree-crop plantations (chapter 2). The leaf litter productions were higher in the first year than in the second year for all the land uses. This trend was the result of more precipitation recorded during the dry season in the second year as compared to the dry spell of the dry season in the first year (Fig. 9).

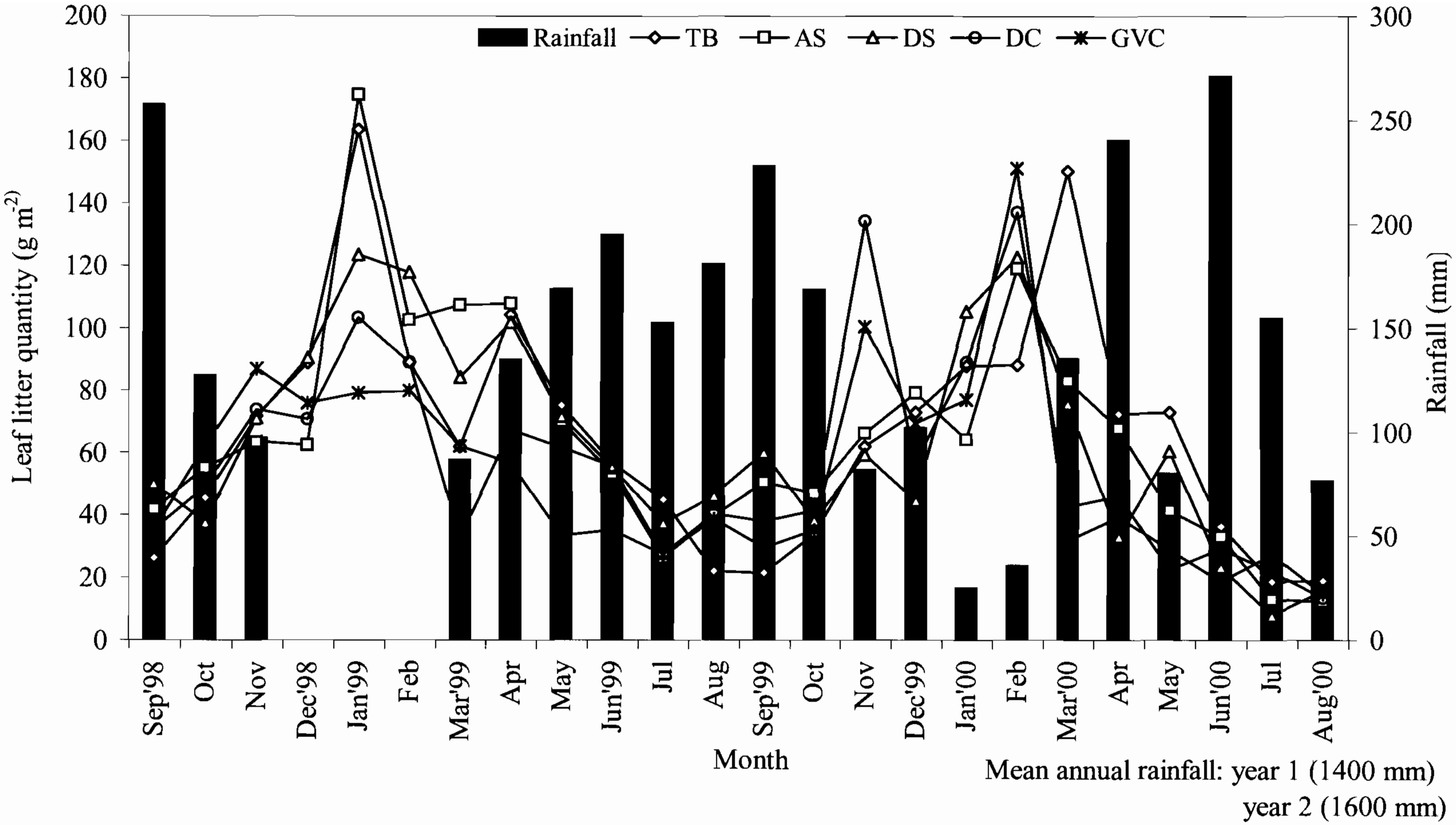


Figure 9: Mean monthly leaf litter productions (g m^{-2}) and mean monthly rainfall (mm) in Dwinyan Watershed for September 1998 to August 2000

The mean annual leaf litter yields obtained for the land uses were higher than those obtained by previous authors (Lim, (1978) obtained 6.4 t ha^{-1} $year^{-1}$, Ogawa, (1978) 6.3 t ha^{-1} $year^{-1}$, Proctor *et al.*, (1983) 5.4 t ha^{-1} $year^{-1}$ and Tanner, (1980) 5.3 t ha^{-1} $year^{-1}$). John, (1973), however, obtained 7.4 t ha^{-1} $year^{-1}$ for tropical semi-deciduous forest leaf litter in Ghana.

The leaf litter fall values obtained for all the land uses of Dwinyan Watershed (Fig. 2) were not significantly different. Gong and Ong, (1983) and Madge, (1965) reported that highest leaf fall occurs when rainfall decreases. Between November and February, when total rainfall was about 12 % of the annual rainfall, the leaf fall production was 40 % of the annual leaf fall. The pattern, however, suggested that the highest leaf fall occurred at the dry months (November to February) in each year (Fig. 9).

Tables 3 and 4 show the quantities of leaf litter fall in the dry, major, minor rainy seasons and the relationships between rainfall amounts and leaf litter productions in the seasons of the land uses. From Table 3, leaf litter productions in the primary, secondary forests and the two cocoa plantations were highest in the dry season and did not differ significantly at $P > 0.05$ between the land uses. During the major rainy season, leaf fall was high and did not differ between the forests land uses but significant differences were observed between the forests and the cocoa plantations at $P > 0.05$. Lowest leaf litter fall was observed in the minor rainy season and did not differ for all the land uses. However, between the seasons and leaf litter productions of the land uses, significant differences were observed (Table 3).

Table 3: Mean leaf litter productions (g m^{-2}) in the dry, major and minor rainy seasons in the various land uses.

	Study sites				
Seasons	T-BPF	AS	DS	DC	GVC
Dry	90.59 [a] (31.27)*	91.58 [a] (39.63)	91.90 [a] (30.53)	94.34 [a] (29.14)	90.09 [a] (26.30)
Major rainy	69.43 [b] (36.95)	60.37 [b] (32.83)	55.13 [b] (29.47)	40.74 [c] (16.59)	36.08 [c] (13.50)
Minor rainy	28.03 [c] (10.03)	41.10 [c] (15.15)	41.36 [c] (14.99)	36.33 [c] (12.18)	35.95 [c] (15.38)

T-BPF = Primary forest **AS** = Akyaakrom secondary forest **DS** = Dopiri secondary forest **DC** = Dopiri Cocoa plantation **GVC** = Gold Valley Cocoa plantation

The same letters within the season under the various land uses are not different significantly at $P > 0.05$.

* Standard deviations are in parenthesis.

In Table 4, leaf litter fall from all the land uses were positively correlated. Conversely, leaf litter fall and rainfall amounts in the seasons were negatively correlated. These relationships obtained indicated that high litter production was as the result of lower or no precipitation and vice-versa.

The seasonality of leaf litter productivity was observed in both years of the study period.

Table 4: Correlation between rainfall distributions and leaf litter productions in the various land uses

	TB	AS	DS	DC	GVC
AS	0.807				
DS	0.743	0.834			
DC	0.520	0.651	0.711		
GVC	0.428	0.630	0.691	0.898	
Rainfall	-0.544	-0.511	-0.659	-0.560	-0.645

24 observations were used in this computation.

Decomposition of leaf litter

The decomposition of a leaf litter did not dependent on the pattern of monthly rainfall. There was gradual but progressive fragmentation and decomposition of the leaf litter throughout the year (Fig. 10). In terms of the decomposition rate, TT was significantly slower than the others for the first to three months but not thereafter. The decomposition rates of TS and TM were similar and seemed to accelerate during December to April. The decomposition rate of TC fluctuated less than TS and TM during the same period.

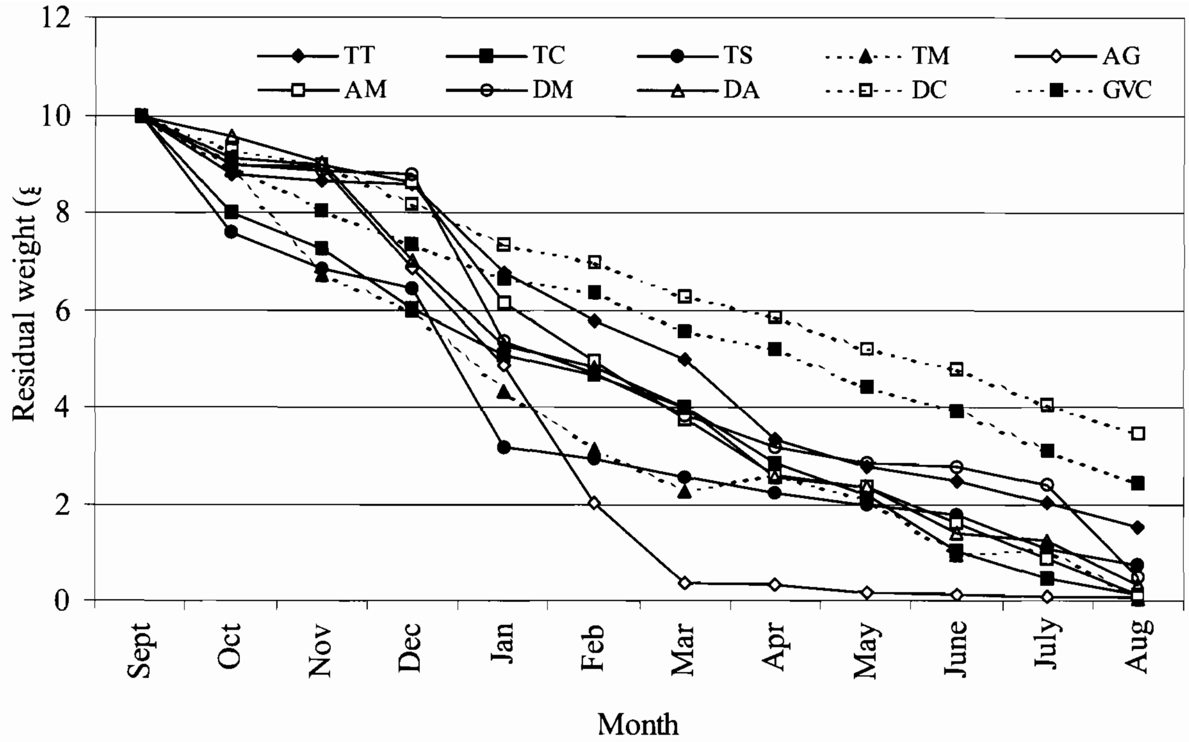


Figure 10: Residual weights (g) and trends of decomposition of leaf litter types in land uses during 12 months of exposure. Initial weights were 10 g.

During fragmentation and material losses, the leguminous tree species, *G. simplicifolia* (AG) showed rapid decomposition in AS. By the end of the 7th month, AG lost more than 90 % of its dry weight. However, the decomposition rate of *A. zygia* (DA) also a legume from DS was almost the same as the mixed tree species leaves (DM) during 9 months of exposure (Fig. 10). The decomposition rate of DM was accounted for by the presence of *A. zygia* leaves contributing more than half of the total species leaves litter produced. Decomposition of mixed leaf litters differed between Akyaakrom (AM) and Dopiri (DM) secondary forests for the 1st to 3rd and 9th to 10th months. The differences in the residual weights of leaf litters among the different types were much smaller after April (7th month) than before it (Fig. 10). The decompositions of leaf litters from the two cocoa plantations followed a similar trend. Decomposition in cocoa leaves was very gradual and extended over the 12 months period. Decomposition of cocoa leaf litter of Gold Valley however, was relatively faster than that of Dopiri (Fig. 10).

Tanner, (1981) reported that the lower rate of decomposition in the upper mountains, as compared to the lowland rainforest was the result of lower temperatures, different leaf characteristics and differences in water relations. The relationship between fluctuation and the rainfall pattern was unclear. Swift *et al.*, (1979) suggested that the decomposer communities, the resource quality and the physicochemical environment regulate decomposition processes. Anderson *et al.*, (1983) has shown that there is no relationship between decomposition and fauna populations. Attempts have been made to relate decomposition rates to physical environmental factors, mainly temperature and moisture. But this could be related to the influence of site differences on a macro-scale (Anderson and Swift, 1983). In this chapter, decomposition of the leaf litter was attributed to the nature or characteristics of the litter and site conditions. However, concentrations of total extractable polyphenols (TEPH) in each leaf litter type well explained the differences in decomposition rates among leaf litter types (Figure 11). TEPH resists decomposition and hence TT, DC and GVC that were high in TEPH, did not decompose much in the first three months. TEPH in TC, TS and TM leaf litter types was remarkably broken down after 3rd month (88%-95% breakdown), but the breakdown of TEPH was slower in TT (66%).

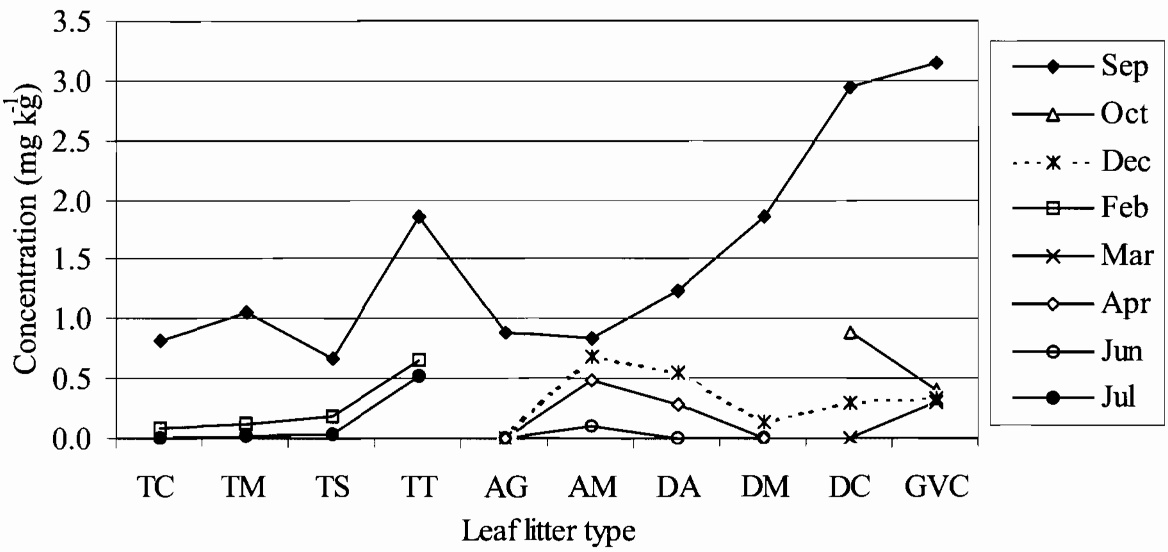


Figure 11: Total extractable polyphenolics (TEPH) concentrations (mg kg^{-1}) in decomposed leaf litters

The differences in the rate of decomposition from the secondary forests could be explained by the differences in the TEPH concentrations in the leaf litter types at different stages of their exposures. TEPH concentrations of fresh leaf litters was highest in DM (1.86 mg kg^{-1}), followed by DA (1.24 mg kg^{-1}), AG (0.89 mg kg^{-1}) and AM (0.84 mg kg^{-1}) in decreasing order. At the 9th month of exposure, only AM contained TEPH concentration of 11%. At the 3rd month, the TEPH in AG had broken down completely whilst that of DM, DA and AM had declined by 93%, 55% and 18%, respectively. The rapid decline of TEPH in AG caused the rapid decomposition of its leaf litter and the slower decline in AM and DA (Fig. 11) delayed their decomposition in Fig. 10.

Unlike loss of leaf material through the decomposition process, the TEPH in cocoa (DC and GVC) leaf litters as shown in Fig. 11 was rather slow especially during the first month between September and October. However, the decline of TEPH was gradual after the first month. TEPH was high in the cocoa leaf litters and until after June-July, the breakdown was slow or not at all and the residual leaf material was small for further analysis. Other factors may have contributed to the fragmentation of the cocoa leaf litter. The subsequent rapid disappearance of TEPH contributed to the faster loss of leaf litter materials as Swain (1979) reported.

Nutrient release from leaf litter

Release of nutrients from leaf litter and monthly changes in the nutrient concentrations of K, Ca, Mg, P and N in leaf litters that were exposed on the soil surface to decomposition is shown in model (Fig. 12) developed.

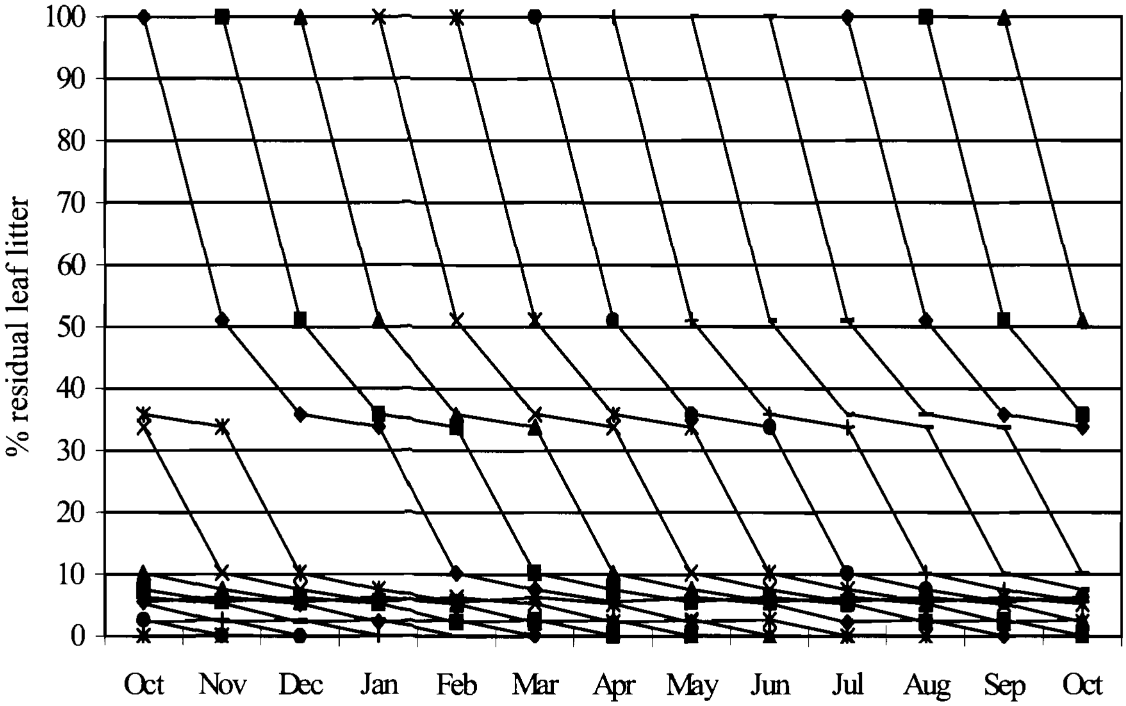


Figure 12: Model of nutrient release from leaf litter in each month

The concentration of K changed the fastest, decreasing during the first month at a rate of 40% for TS to 68% for TM. Changes in Mg and P concentrations were moderate in all the litter types. Calcium and N concentrations decreased at slower rates especially, TT and TM released N very slowly. Indeed, decomposed litters showed higher N concentrations than did fresh leaf litters. This increase in N could be attributed to microbial immobilization or to some nitrogen fixation using the carbon source of the litter.

In all the leaf litter types, nutrients were generally released as decomposition progressed. There were differences between litter types in the rate of nutrient release in the first few months of decomposition as observed by Songwe *et al.*, (1995). Calcium in TC decreased very slowly whilst N in TT and TM litters increased temporarily at the beginning of decomposition i.e. the first month (Fig. 13a). Both of these resulted from increases in concentrations of the elements in residual leaf litters. Bernhard-Reversat, (1972) reported that the mineralization of Ca is related to the disappearance of organic matter since it is used in building cell walls in plants and the presence of shielding substances such as lignins, tannins and so on.

Nitrogen fixation or the build up of N by microbial activities in the decomposed leaf litters was thought to contribute to the increase of nitrogen. Further exposure showed gradual declines of Ca and N as well as the other nutrients. The release of Mg and P was gradual and near linear during the first 4 months, whilst K was released very rapidly during the first 2 months of exposure. Nutrient releases of K, Mg and P did not differ between the leaf litter types throughout the decomposition periods. More than 95% of the nutrients were released from all leaf litter types within 9 months, except for N. Nutrients were released in the following decreasing order of K > P > Mg > Ca > N.

The rate of nutrient release was generally faster than the rate of dry mass loss of a leaf litter during the decomposition especially in its early period. For example, TT was decomposed and its dry mass/weight decreased by only 14% for the first 3 months. However, nutrients such as K, Ca, Mg and P decreased at 81%, 42%, 44%, and 49% respectively. Other leaf litter types also showed this trend (Fig. 13 a).

Generally, nutrient concentrations decreased gradually as the leaf litter decomposed. Concentration of K in AM showed a quick 73% decrease at the 3^{rd} month. However, K concentrations in AG and AM decreased very slowly or not at all. As expected, Ca was released at a relatively slower rate than any of the nutrients from all the leaf litter types. The decline of P concentration was slower which might be due to the low P concentration in the fresh leaves litters in the secondary forests. Nitrogen concentrations however, appeared to increase during the decay process (Fig. 13 b).

The progressive increase of N in the residual leaf litters indicated that either it was immobilized and accumulated or that the litter acted as a sink for N as reported by Maheswaran and Gunatilleke, (1988). The build up of N initially in decomposing litter through translocation and accumulation or immobilization of N for the build up of microbial tissues contributed to its accumulation in the decomposing litters as reported by O'Connell, (1988) and Songwe *et al*, (1995).

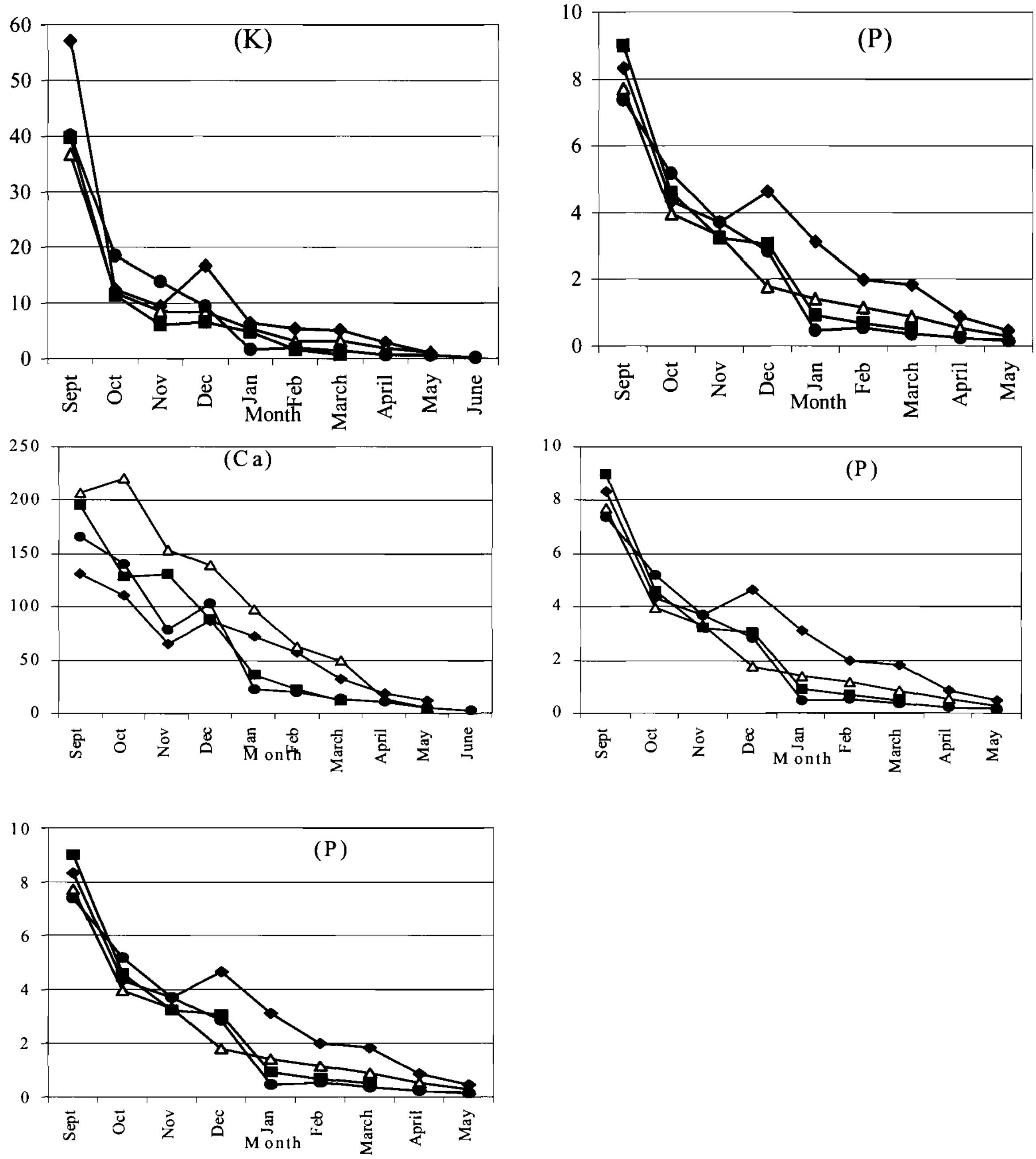


Figure 13a: Nutrient amounts (mg) remaining in residual leaf litters from the primary forest during monthly decomposition

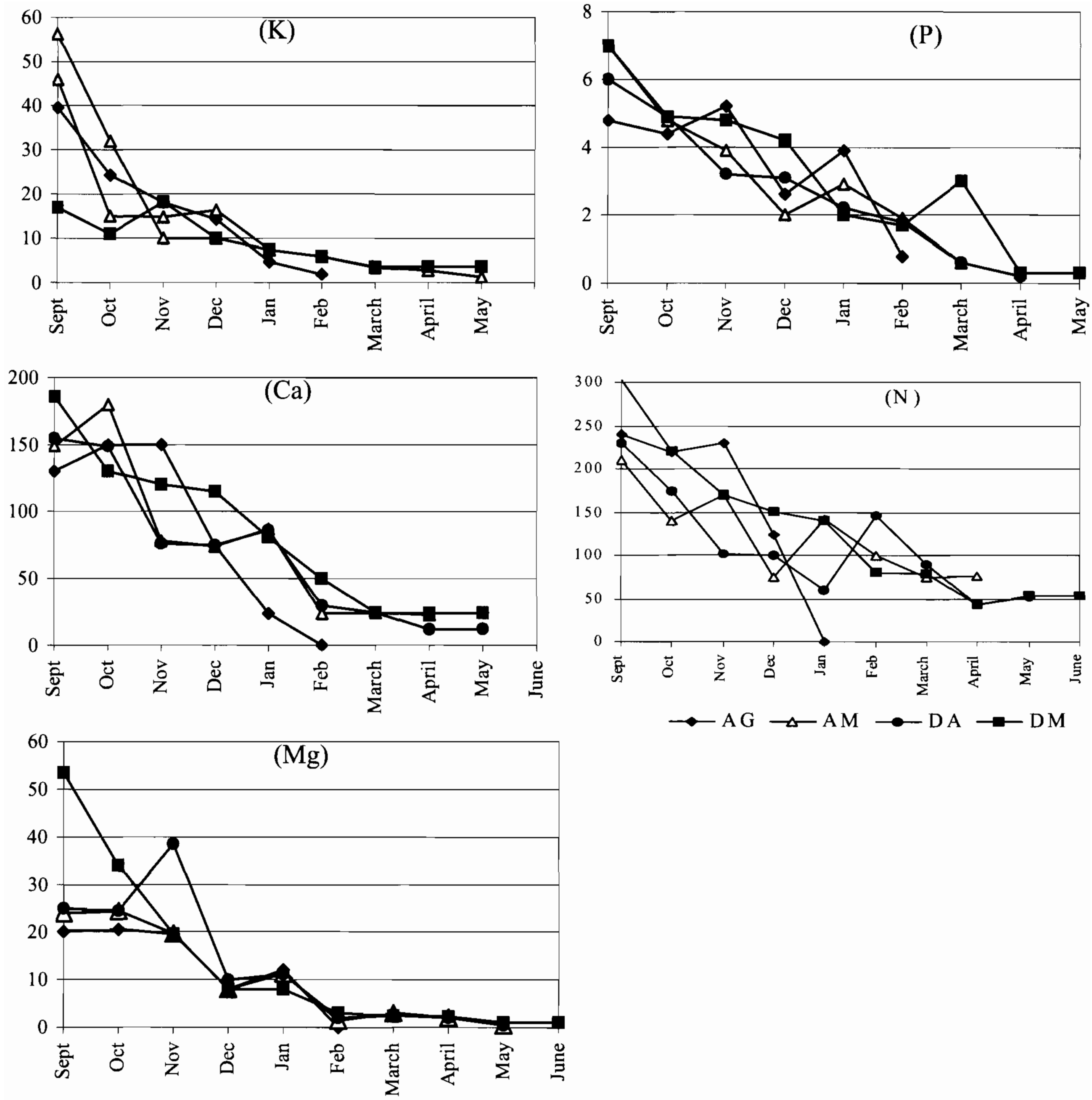


Figure 13b: Nutrient amounts (mg) remaining in residual leaf litters from the two secondary forests during monthly decomposition

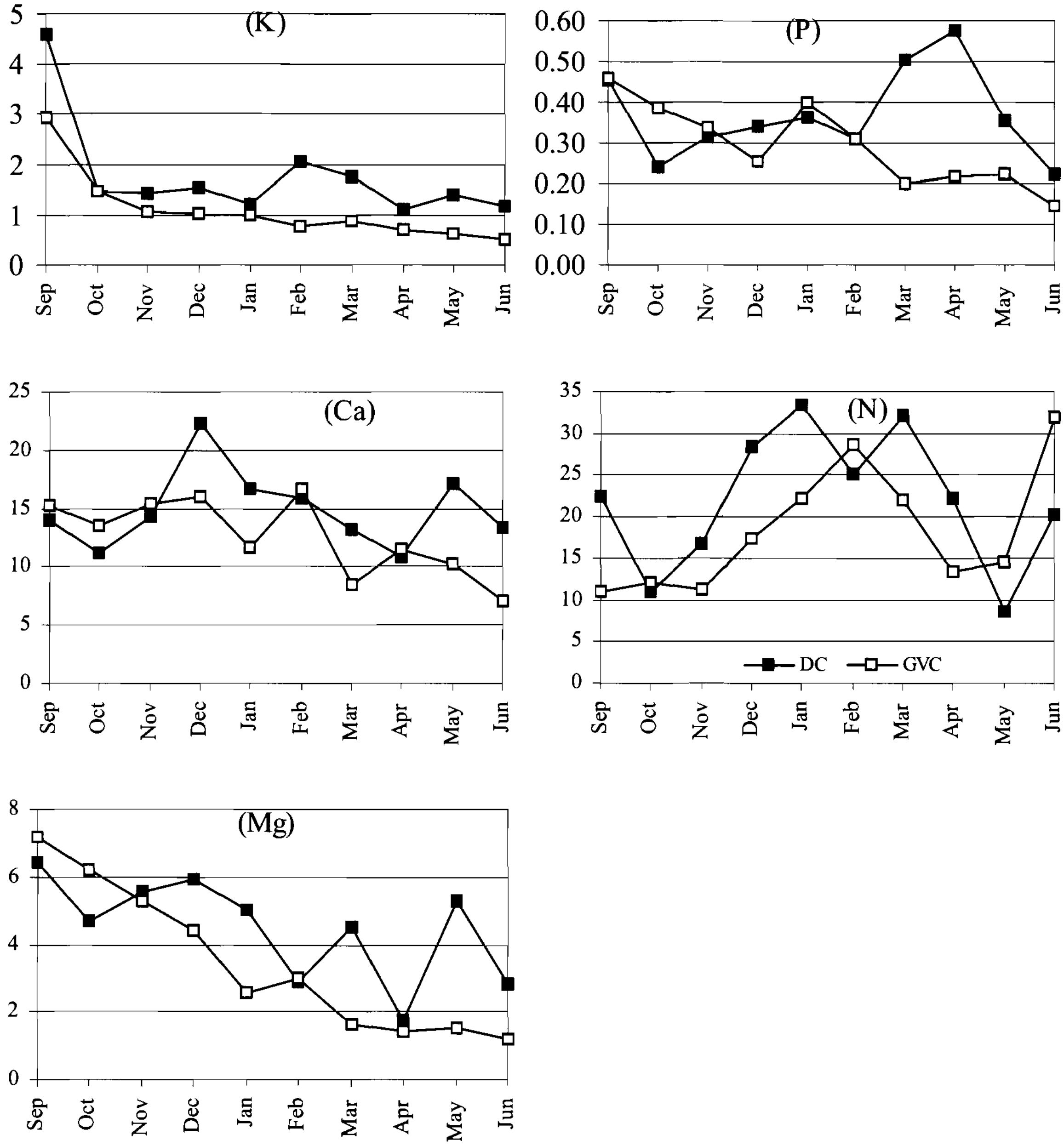


Figure 13c: Nutrient amounts (mg) remaining in residual leaf litters from the two cocoa plantations during decomposition

Table 5: Total nutrient element concentrations (g kg^{-1}) in residual leaf litter types from the land uses at the end of decomposition periods

	Element Concentration (g kg^{-1})				
Leaf litter type	K	Ca	Mg	P	N
TT	0.06[a]	0.46[a]	0.12[c]	0.02[a]	1.29[a]
TC	0.04[a]	0.74[b]	0.07[c]	0.01[a]	0.91[b]
TS	0.05[a]	0.40[a]	0.05[c]	0.01[a]	0.83[b]
TM	0.03[a]	0.42[a]	0.05[c]	0.01[a]	0.82[b]
AG	0.10[a]	0.53[a]	0.06[c]	0.02[a]	0.57[b]
AM	0.13[a]	0.64[b]	0.07[c]	0.02[a]	0.78[b]
DA	0.11[a]	0.62[b]	0.09[c]	0.02[a]	0.77[b]
DM	0.08[a]	0.76[b]	0.08[c]	0.03[a]	0.99[b]
DC	0.14[a]	0.26[c]	0.69[a]	0.02[a]	0.08[c]
GVC	0.08[a]	0.15[c]	0.48[b]	0.01[b]	0.05[c]

The leaf litter type with the same letters under each of the elements was not significant at P > 0.05.

The decomposition process was completed within a year and all nutrient elements except N was released within a year. The leguminous tree *G. simpliciffolia* (AG) decomposed and released nutrient faster than the other leaf litter types. Nutrients releases were prolonged in the leaf litters of the mixed leaves treatments from the two secondary forests (Fig.13b). The elements, N, P, K, Ca and Mg were analyzed from the decomposed cocoa leaf materials collected every month. The release of K and Mg in Gold Valley cocoa leaf litter followed the loss of leaf material during decomposition. The loss of K and Mg was rapid. However, the release of K from the Dopiri cocoa leaf litter was relatively slower and was partially immobilized in January-February and April-June, whilst Mg release was not consistent and was characterized by release and immobilization (Fig. 13c and Table 5).

Calcium and P did not assume any trends in their releases from the two cocoa leaves litters. But after April (8^{th} month), there were rapid declines of Ca and P from the decomposed cocoa leaves litters. About half of the concentration of N was released during first month of decomposition in Dopiri, but build up occurred for four months (October- January). This trend continued throughout the year. In the Gold Valley, decomposition was characterized by initial build up for a month, released for another month and built up again for three months after which it was released. Towards the end of decomposition period, N concentration increased in the two cocoa leaf litters indicating that N was added from the atmosphere or from the soil (Fig. 13c). Generally, cocoa leaves decompose relatively slower. TEPH and other factors such as moisture, temperature and leaf characteristics influenced decomposition.

Nutrient flux from leaf litters

The pattern of nutrient flux was similar to that of leaf litter production and the residual nutrients as shown in Figs. 9 and 13, respectively. From Figs. 9, 10, 12 and 13 and equations 1 and 2, the estimated mean annual nutrient fluxes were 157 kg ha^{-1} yr^{-1} for Ca, 166 kg ha^{-1} y^{-1} for N, 32 kg ha^{-1} y^{-1} for K, 23 kg ha^{-1} y^{-1} for Mg and P was least of 7 kg ha^{-1} y^{-1}. Though, the estimated flux for N did not account for denitrification losses, however, nutrient fluxes in the Tinte-Bepo Reserved primary forest revealed rich nutrient cycling to sustain low levels of soil fertility (Annan-Afful, *et al.*, 2001) (Table 6).

Similarly, nutrient fluxes from the leaf litters for each month were estimated for each of the secondary forests. The mean annual nutrient fluxes were: N, 172 and 236 kg ha^{-1}; Ca, 119 and 149 kg ha^{-1}; Mg, 42 and 19 kg ha^{-1}; K, 44 and 13 kg ha^{-1}; and P, 6 and 5 kg ha^{-1} in AS and DS, respectively. However, the differences in leaf litter production, decomposition trends based on the leaf characteristics and the nutrient release patterns in each site led to the differences in the amount and patterns of the nutrient fluxes in the two secondary forests (Table 6).

Table 6: Mean annual leaf litter productions (t ha^{-1}) and nutrient fluxes (kg ha^{-1}) from decomposed leaf litters to soil surface from the land uses.

Site	Leaf (t ha^{-1} y^{-1})	Nutrient element (kg ha^{-1} y^{-1})				
	Litter	N	P	K	Ca	Mg
T-BPF	7.9	166	7.2	32	157	23
AS	7.9	172	5.6	44	119	19
DS	6.7	236	5.4	13	149	42
DC	7.1	104	6.7	16	95	7
GVC	6.7	111	2.5	7	110	3

T-BPF = Primary forest **AS** = Akyaakrom secondary forest **DS** = Dopiri secondary forest **DC** = Dopiri Cocoa plantation **GVC** = Gold Valley Cocoa plantation

The mean annual nutrient fluxes estimated from the two cocoa plantations were: N, 104 and 111 kg ha^{-1}; P, 6.7 and 2.5 kg ha^{-1}; K, 16 and 7 kg ha^{-1}; Ca, 95 and 110 kg ha^{-1}; Mg, 7 and 3 kg ha^{-1} for DC and GVC, respectively (Table 6). The nutrients were released to the soil surface by the processes of disintegration, fragmentation of the leaf litter into humus and followed by mineralization. Nitrogen was usually lost through denitrification or the decomposer communities used it to build their bodies. K and P were deficient in the soil of the watershed.

The nutrient flow from these upland soils into the lowlands may enrich the lowland soils to some extent. The choice of establishing forests rather than clearing either by farming or otherwise at the uplands of Dwinyan Watershed for the benefit of the lowland fertilization is favoured. However, plantations may be established with leguminous tree species in association to ensure faster decomposition and mineralization of fallen litter. Thus, the release of held up nutrients may be enhanced to fertilize the lowlands for other cropping systems.

Chapter 4

INTERGRATED AGROFORESTRY FOR SUSTAINABLE "SAWAH" FARMING SYSTEMS

4.1 Introduction

The tropical rainforest is earth's most complex biome in terms of both structure and texture of the species diversity. The forest canopy is of critical importance for a variety of life processes in our biosphere. The canopy elements house the photosynthetic machinery of the forest, influence the exchange of energy and matter with the atmosphere, and control the microclimate and reduction of wind speed. Trees pump nutrients into the underground ecosystem. In addition, litter from tree contributes to organic matter on the forest floor adding material for the decomposition and energy cycle (Parker, 1994). Trees do not only provide farmers with a range of products, they also play an important role in maintaining the productivity of farming systems. Appropriate agroforestry systems improve soil physical properties, maintain soil organic matter and promote nutrient cycling (Sanchez, 1987).

The forest canopy is a world of surfaces that interact with the atmosphere and acts as a buffer between the soil and the atmosphere. This buffer contributes to the health of the ecosystem by protecting the soil from erosion and by removing particles and pollutants from the air and rain. As much as 20% of bulk precipitation can be intercepted and filtered in a broadleaved canopies. The complex structure of the rainforest canopy allows a huge range of plant species to exist (Parker and Russ, 2004).

The details of how crown material is organized in space are important for prediction of forest functions like growth and habitat complexity (Parker, 1995). The diversity of trees in a stand or landscape will depend on the relative growth, reproductive, and mortality responses of particular species to the local environment - which is strongly determined by the canopy structure (Parker and Russ, 2004). The physiognomy and texture of the outer canopy necessarily constrains some aspects of the internal structure included below that surface (Parker and Russ, 2004). In cocoa agroforestry, it is recommended that farmers preserve trees that have a high crowns and deep roots, not brittle and break in storms to damage cocoa trees. During food crops farming in the forest zone, the low input agriculture farmers need to preserve some trees to maintain the soil structure and protect it against elements (Amanor, 1996). These preserved trees build up stocks of these trees in fallow.

The Asian "Sawah" development looks at the total watershed of which the valleys are used for rice cultivation. In Ghana, the traditional rice cultivation is practiced. The rice yield has often been low and has remained at 1.6 t ha^{-1} yr^{-1}. Vegetations are destroyed during the rice cultivation in the uplands leading to ecosystems degradation. The biodiversity destruction necessitated the re-direction of Ghana's forest policy guidelines on forest conservation. Land use strategies that would ensure environmental sanitation and conservation were required to reverse the trends of forest destructions. The sawah system of rice cultivation was introduced to develop sustainable production system that allows intensification of the lowland rice production system and stabilizing production systems on the uplands. Thus, one hectare of sawah developed opens the field for afforestation in the degraded upland field. The forestry aspects to integrate into the sawah agricultural technology were to characterize tree species diversity, material and nutrients flow between the land uses most especially, the forest types on the uplands and to encourage the participating communities for reforestation of the degraded parts of the uplands and to diversify income of the selected project community members within the framework of Ghana's new forest policy.

Objective

This study was to determine whether or not the structure of the forest canopy and crowns complexities and the trees characteristics could be evaluated for agroforestry farming systems in Ghana.

4.2 Materials and Methods

Tinte-Bepo Forest Reserve in Ashanti Region of Ghana is located between latitudes 6° 33'N and 7° 03'N, longitudes 1° 55'W and 2° 06'W. The average elevation is about 365 m above sea level. The total area of the reserve is about 11,554 ha. The nearest village to the reserve is Bonsukrom about 5 km (Fig. 1). But several farm huts are scattered along the boundaries of the reserved forest. This study was carried out in the Eastern Block; compartment 3, block 6 (striped) (Fig. 2). The compartment is the Forest Management Unit (FMU) 36 and covers 2,934.5 ha. It lies in the drier part of moist semi-deciduous forest type (Hall & Swaine, 1976) and agrees fairly closely in range with the *Celtis-Triplochiton* Association (Taylor, 1960). It has been relatively disturbed than the other parts of the forest because, farm huts are scattered close to the boundaries of the compartment. Law protects the primary forest and entry is by permit obtained from Ghana Forestry Commission. Permits are granted to harvest only timber tree species periodically. However, fringe community members illegally enter the forest to harvest game, non-timber forest products and firewood which is unlimited (Owusu-Sekyere *et al*, 2006).

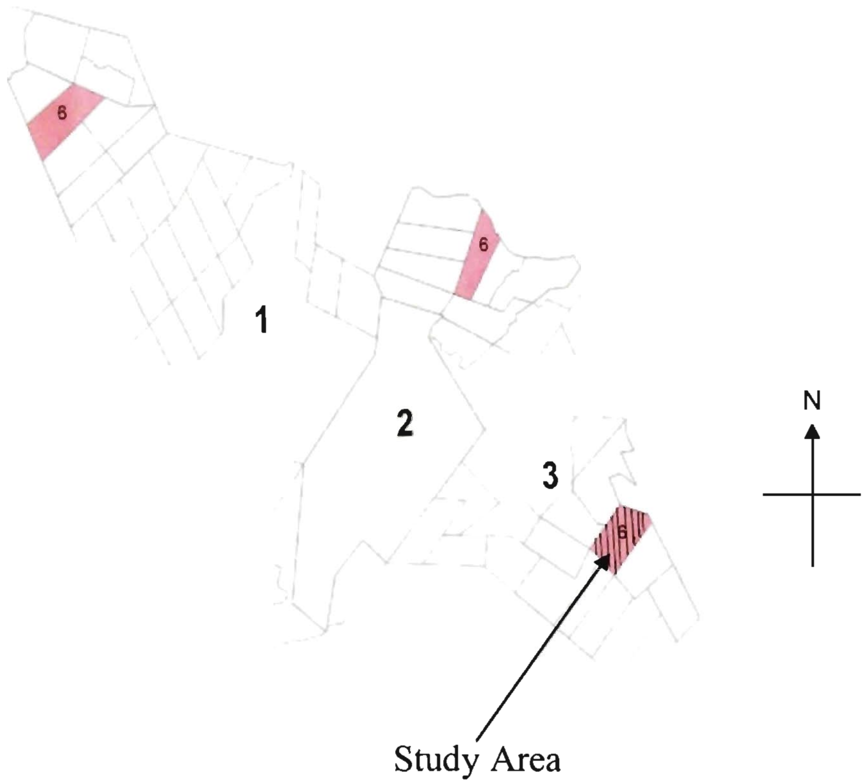


Figure 14: Map of Tinte-Bepo Forest Reserve showing the Eastern Block; Compartment 3, block 6 (striped)

One hectare plot (50 m x 200 m) was demarcated in compartment 3, block 6 (FMU 36). The plot was further sub-divided into small plots of 10 m x 10 m (Fig. 14) and 45 of such unit plots were sampled taking cognizance of topography and hydromorphic characteristics. Tree species above 5.0 cm diameter at breast height (dbh) were tagged and given identification numbers.

All the tagged tree species were identified with help of a forest taxonomist assisted by three local people. Diameters (dbh) of the species were recorded using a diameter tape and heights were measured using a measuring pole. The speleogist gear was used to climb very tall trees for the height measurements. For many researches of canopy structure, single rope technique (SRT), belts or ascenders or ladders (Moffett, 1993) is used to gain direct access to the canopy. These methods are relatively cheap, but are slow, require skill, and are very limited in spatial extent. The altitudes of all the unit plots were taken using the GPS. Points of equal heights were joined together to represent the contours of the entire study plot. Tree positions in the unit plots were also recorded by the GPS points and were represented by their identification numbers (Figure 15).

Nutrient and material cycling

Nutrient and material cycling have been reported in chapters 2 and 3 in this report.

4.3 Results and Discussions

The slope was increasing from 10 m at plot 1 to 13 m in plots 15 and 16 and dropped south-eastwards to 3 m in plot 31 and southwards to 0 m for plots 44 and 45. No single species was dominated the study plot (Fig. 15).

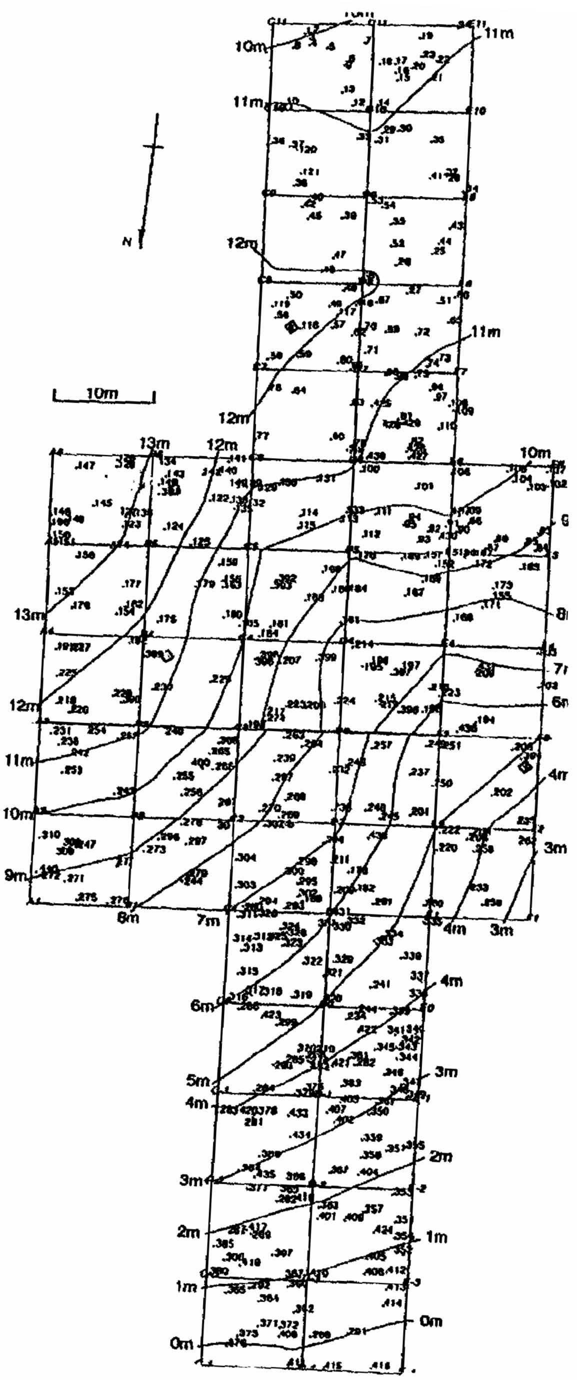


Figure 15: Topography, tree positions and their distribution in the study plot

For the texture of the tree crowns (Fig. 16), there were gaps in the canopy thereby allowing light to be filtered through to the forest floor

(Plate 1). Some of the tree species with quite extensive crowns were tree numbers 19 (*P. macrocarpa*) in plot 2; 76 (*C. zenkeri*) and 79 (*L. trichilloides*) in plot 9; 180 (*C. pachyceras*) in plot 17; 168 (*C. nitida*) in plot 20; 217 (*E. angolense*) in plot 23; 230 (*C. zenkeri*) in plot 24; 226 (*E. ivorense*) in plot 25; 270 (*T. tessmanii*) in plot 28; 249 (*C. gabunensis*) and 257 (*S. oblonga*) in plot 29; 233 (*M. barteri*) in plot 31; 279 (*P. africanum*) in plot 34; 283 (*R. heudelotii*), and 370 (*I. campanulata*) in plot 38; 367 (*C. nitida*) in plot 40 and 415 (*P. macrocarpus*) in plot 45 (Fig. 16) .

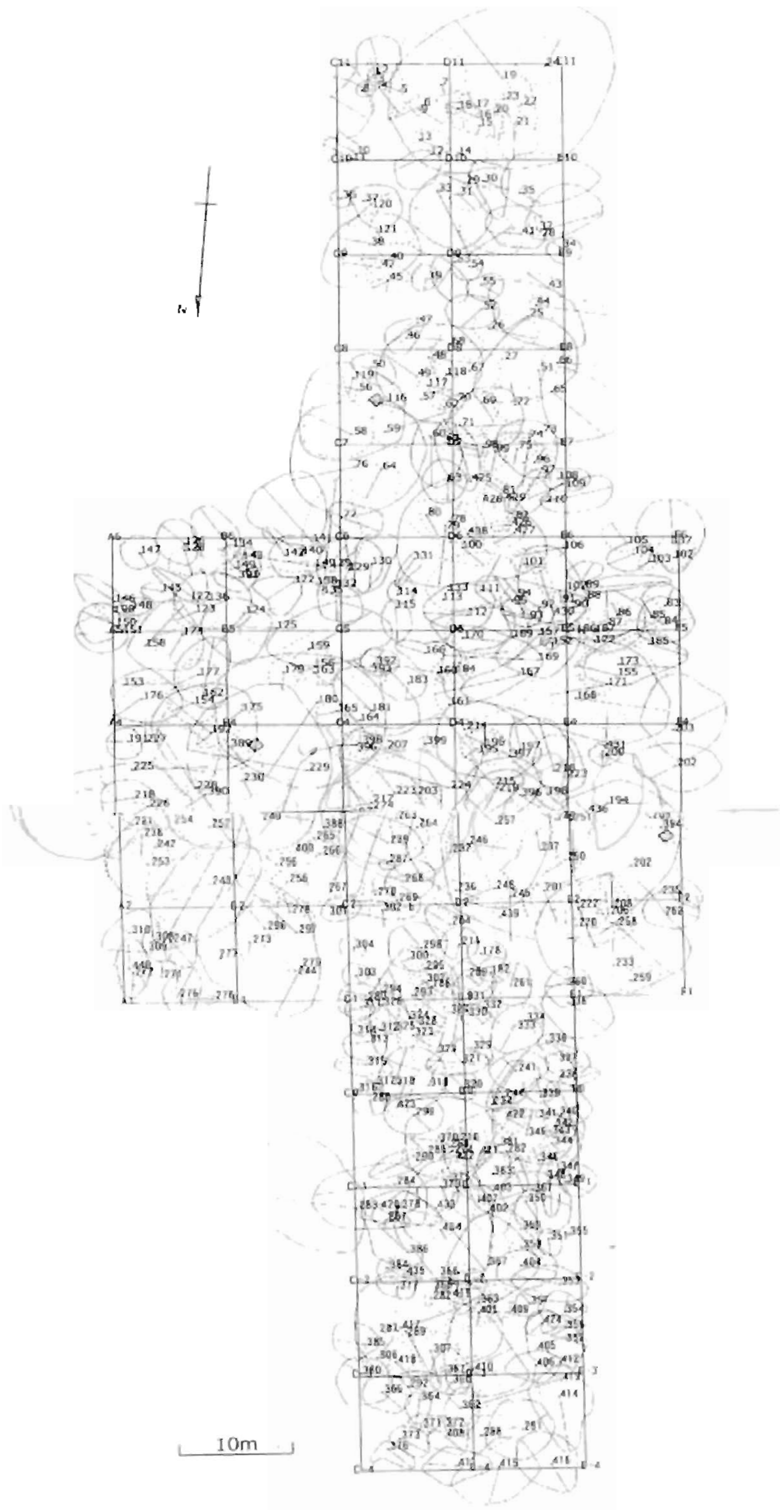


Figure 16: Tree crown projections of enumerated tree species > 5.0 cm dbh.

Probably, the trees species with extensive crowns were the very tall trees (emergent) as can be observed in Plate 1. These were the crowns that were fully exposed from above. The tree species with relatively smaller crowns i.e. partially exposed and those that were fully overshadowed were the lower storied trees.

Plate 1: A canopy picture taken from the ground

Tree species guilds are referred to the nature of the species with respect to canopy gaps, disturbance and light. The pioneer (P) guild is defined as those species which are light demanders just before germination. The Non-pioneer light demander (NPLD) guild require gaps to develop beyond the saplings whilst the Shade-bearer (NPSH) guild is often seen as 'understorey trees' (Hawthorne, 1995). Majority of tree species belonged to less than 45 cm diameter classes and were mostly non-pioneer light demanders and shade-bearers. The populations of the pioneer species were low and only a few belonged to the 60 cm and above diameter class. On the contrary, the NPLD and NPSH species guilds populations were dominant with a comparatively greater number of their sizes above 60 cm dbh (Fig. 17).

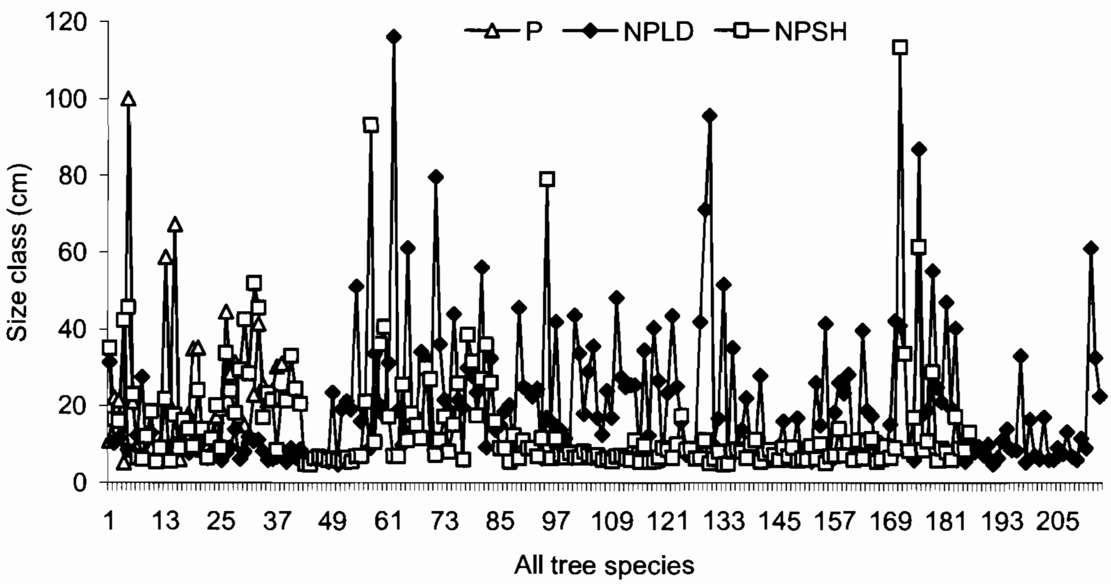


Figure 17: Size class (cm) distribution of individual tree species > 5.0 cm dbh in their guilds

Where P = Pioneer; NPLD = Non-Pioneer Light Demander; NPSH = Non-Pioneer Shade Bearer

As indicated in Fig. 18, pioneer species (P) represented 8.7% of individual tree species in the entire plot, 49.1% and 42.2% were non-pioneer light demanders (NPLD) and shade bearers (NPSH), respectively. It could be concluded that though the forest has suffered from some disturbances, too many gaps have not been created for rapid colonization by the pioneer tree species or that the pioneer species failed to survive in the small gaps or that the reserve has been well protected and managed.

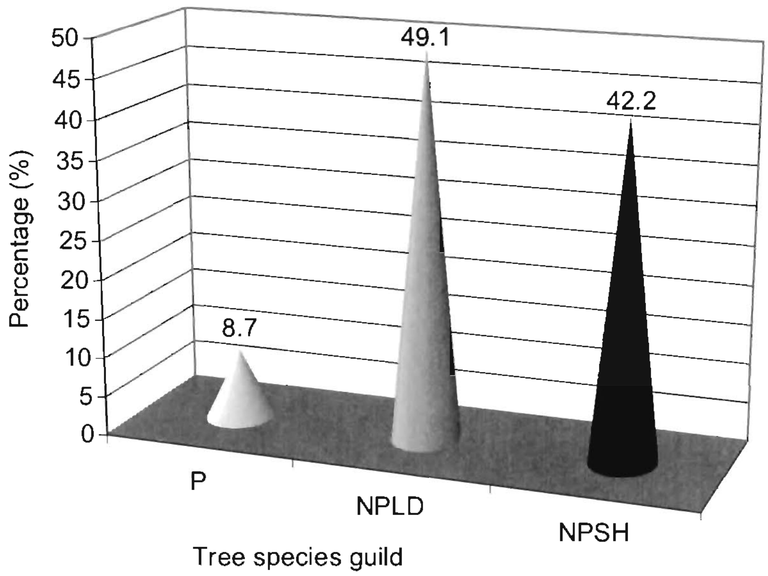


Figure 18: Percentage (%) populations of tree species guilds in the study plot

The canopy layers were defined as: A-layer (> 30 m); B-layer (15 – 30 m) and C-layer (5 – 15 m). From Figure 19, the emergents that occupied the A-layer were only 3.7%. The B-layer in the canopy was 11.6% whilst the C-layer dominated in the study plot and recorded 84.7% of all the tree species greater than 5.0 cm dbh (Figure 19).

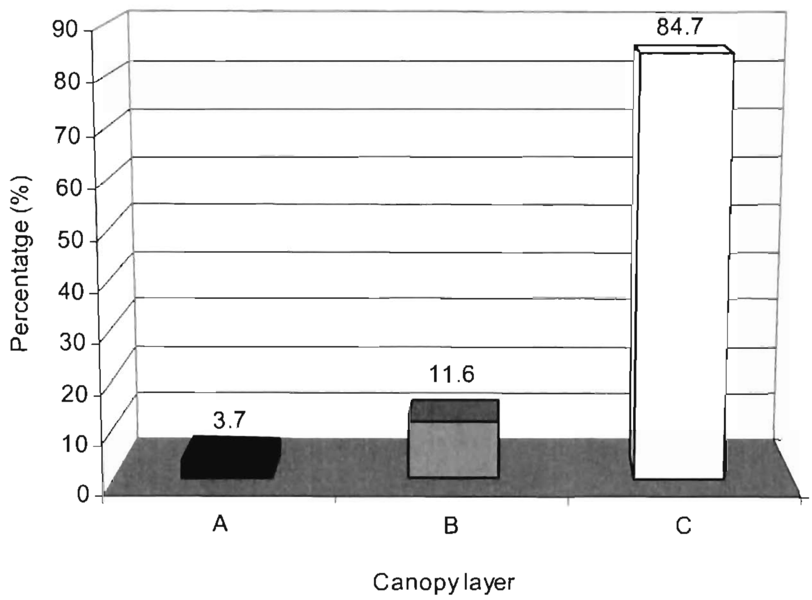


Figure 19: Percentage (%) of tree species in the layers of the canopy

Generally, the distribution of all tree species in the study plot is an indication of high tree diversity. However, the diversity indices were limited to the canopy layers.

Representations of tree species guilds (percent) in the canopy layers are shown in Figure 20. Within each of the species guilds, the C-layer contained more tree species (94% for NPSH; 84% for NPLD and 77% for P tree species) which were higher than A and B-layers. Tree populations in the middle layer (i.e. B-layer) ranged 3.8 to 18.6% and were highest for the NPLD guilds (18.6%) and least for the shade-bearer tree species (3.8%). Only a few (about 2%) of the shade-bearers guild showed up as emergent. For the populations of all tall tree species in the A-layer (emergent), NPLD and P tree species guilds were more than twice as much as that of NPSH (4.7 and 5.3%, respectively) (Figure 20).

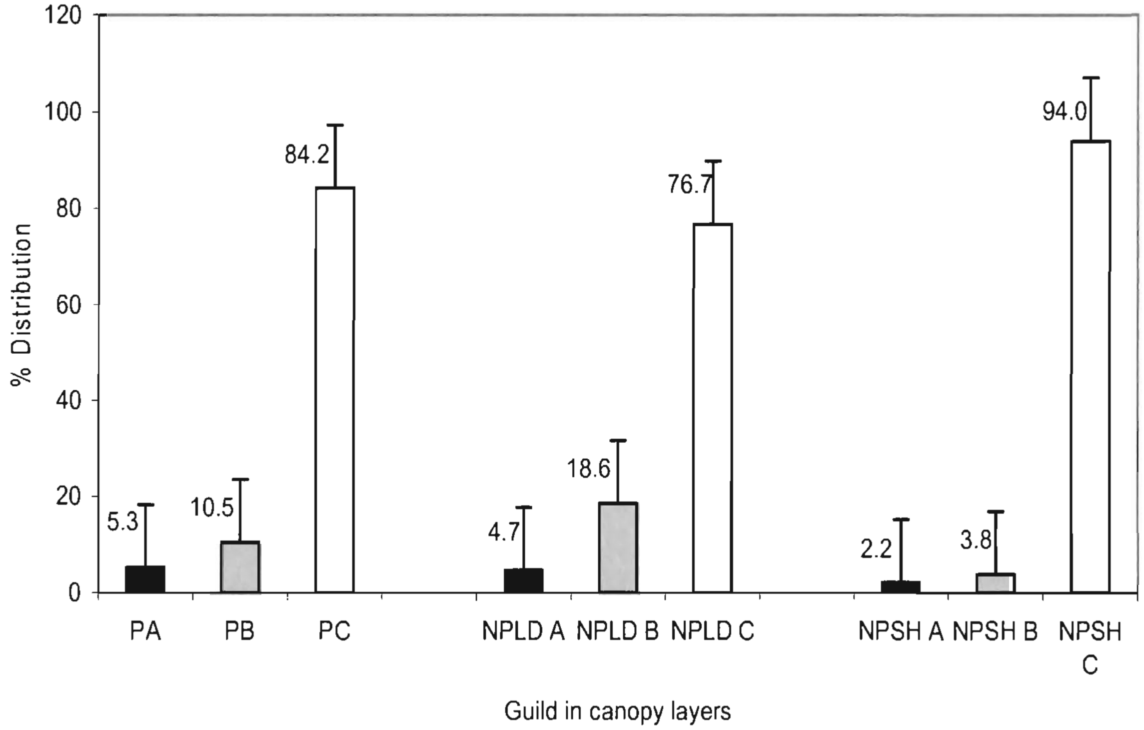


Figure 20: Percentage (%) of individual tree species in their guild as distributed in the canopy

The vertical bars indicate standard errors

Out of a total of 436 tree species encountered in the study area, populations of the pioneer species were low and its diversity was 21.6% whilst 41.9% and 36.5% diversities were recorded for the non-pioneer light demanders and the shade bearers, respectively. From Table 7, the 'emergent' pioneer species recorded were *Anthocleista nobilis* and *Daniella ogea*. The shade-bearers are considered to be understorey tree species but *Allanblackia parviflora, Anthonotha macrophylla, Cola nitida, Dialium aubrevillei, Isolona campanulata, Massularia acuminata* and *Nesogordonia papaverifera* were recorded as B-layer tree species of the canopy. More significantly, *Craterispermum caudatum, Mammea africana,* and *Nesogordonia papaverifera* known to be shade-bearers were recorded in the category of emergent (A-Layer).

The pioneer species generally recorded very large canopy exposures. The architecture of these species is such that their seedlings or pole stage plants had small to medium crown spreads. The pioneer species that were encountered in the understorey (C-layer) but had large crowns were *M. heterophylla*, *P. macrocarpus* and *R. heudelotii.* The shade-bearers with large canopies were *C. gabunensis*, *D. klaineana, D. dinklagei, M. barteri, M. acuminata, N. papaverifera, T. discolor* and predominantly occupied the C-layer.

Table 7: Number, crown sizes and guilds of individual tree species that were common to the canopy layers

Species Name	**Family**	**Guild**	**Canopy layer**	**Crown size**	**No. of trees**
Albizia adianthifolia	Mimosaceae	NPLD	C	M	1
Allanblackia parviflora	Guttiferae	NPSH	B,C	S, M	8
Alstonia boonei	Apocynaceae	P	C	S	1

Amphimas pterocarpoides	Caesalpiniaceae	NPLD	C	S	2
Aningera robusta	Sapotaceae	NPLD	B,C	M, L	5
Anthocleista nobilis	Loganiaceae	P	A,C	S, M	11
Anthonotha macrophylla	Caesalpiniaceae	NPSH	B,C	S	3
Aulacocalyx jasminiflora	Rubiaceae	NPSH	C	S, M	10
Baphia nitida	Papilionaceae	NPLD	B,C	S	39
Baphia pubescens	Papilionaceae	NPLD	B	S	4
Blighia sapida	Sapindaceae	NPLD	C	S, M, L	6
Blighia welwitschii	Sapindaceae	NPLD	B	M, L	2
Bombax buonopozense	Bombaceae	P	B	M	1
Ceiba pentandra	Bombaceae	P	C	S	1
Celtis mildbraedii	Ulmaceae	NPSH	C	S	2
Celtis zenkeri	Ulmaceae	NPLD	A,B,C	S, M, L	34
Chrysophyllum albidum	Sapotaceae	NPSH	C	M	1
Cola millenii	Sterculiaceae	NPLD	C	S, M	7
Cola nitida	Sterculiaceae	NPSH	B,C	S,M	18
Corynanthe pachyceras	Rubiaceae	NPLD	B	S, M, L	27
Craterispermum caudatum	Rubiaceae	NPSH	A,C	S	13
Cylicodiscus gabunensis	Mimosaceae	NPSH	C	S, L	3
Dacryodes klaineana	Burseraceae	NPSH	C	L	1
Daniella ogea	Caesalpiniaceae	P	A	L	1
Daniellia thurifera	Caesalpiniaceae	P	C	S	1
Dialium aubrevillei	Caesalpiniaceae	NPSH	B,C	S, M	4
Dialium dinklagei	Caesalpiniaceae	NPSH	C	S, M, L	8
Diospyros gabunensis	Ebenaceae	NPSH	C	S	1
Disthemonanthus bentamianus	Caesalpiniaceae	NPLD	B	S	1
Enantia polycarpa	Annonaceae	NPLD	C	S, M	2
Entandrophragma angolense	Meliaceae	NPLD	A	M, L	2
Entandrophragma cylindricum	Meliaceae	NPLD	C	S	1
Entandrophragma utile	Meliaceae	NPLD	C	S	1
Erythrophleum ivorense	Caesalpiniaceae	NPLD	A	L	1

Funtumia elastica	Apocynaceae	NPLD	B,C	S, M, L	19
Greenwayodendron oliveri	Annonaceae	NPSH	C	M	1
Holoptelea grandis	Ulmaceae	P	C	S	1
Homalium stipulaceum	Flacourtiaceae	NPLD	C	S	2
Irvingia gabunensis	Irvingiaceae	NPLD	C	S	1
Isolona campanulata	Annonaceae	NPSH	B	S, M	7
Khaya ivorensis	Meliaceae	NPLD	B,C	M, L	5
Lannea welwitschii	Anacardiaceae	P	C	M	1
Lecaniodiscus cupanioides	Sapindaceae	NPSH	C	S, M	4
Lovoa trichilloides	Meliaceae	NPLD	B,C	S, M, L	6
Macaranga heterophylla	Euphorbiaceae	P	C	S, M, L	1
Maesobotrya barteri	Euphorbiaceae	NPSH	C	S, M, L	8
Mammea africana	Sapotaceae	NPSH	A	L	1
Magaritaria discoidea	Euphorbiaceae	P	B	S, M	2
Massularia acuminata	Rubiaceae	NPSH	B,C	S, M, L	16
Memecylon lateriflorum	Melastomataceae	NPSH	C	S, M	16
Microdesmis puberula	Pandaceae	NPSH	C	S, M	26
Monodora tenuifolia	Annonaceae	NPSH	C	S, M	12
Morus mesozygia	Moraceae	P	C	S	1
Myrianthus libericus	Moraceae	NPSH	C	S	3
Napoleonaca vogeli	Lecythidaceae	NPSH	C	S	2
Nesogordonia papaverifera	Sterculiaceae	NPSH	A	S, M, L	6
Pentaclethra macrophylla	Mimosaceae	NPLD	B	M	1
Petersianthus macrocarpus	Lecythidaceae	P	C	S, M, L	5
Piptadeniastrum africanum	Mimosaceae	NPLD	A,C	M, L	4
Pterygota marcrocarpa	Sterculiaceae	NPLD	A,B,C	S, M, L	6
Ricinodendron heudelotii	Euphorbiaceae	P	C	S, M, L	8
Sterculia oblonga	Sterculiaceae	NPLD	A,B,C	M, L	4
Sterculia rhinopetala	Sterculiaceae	NPLD	C	S	1
Strombosia glaucescens	Olacaceae	NPSH	C	S, M	5
Terminalia ivorensis	Combretaceae	P	C	M	1

Tricalysia discolor	Rubiaceae	NPSH	C	M, L	4
Trichilia monadelpha	Meliaceae	NPLD	C	S, M, L	7
Trichilia prieuriana	Meliaceae	NPLD	B,C	S, M, L	18
Trichilia tessmanii	Meliaceae	NPLD	C	M, L	2
Trilepisium madascariense	Moraceae	NPLD	B	L	2
Triplochiton scleroxylon	Sterculiaceae	P	B	L	1
Uapaca corbisieri	Euphorbiaceae	NPLD	C	L	1
Xylopia aethiopica	Annonaceae	P	B	L	1
Xylopia quintasii	Annonaceae	NPSH	C	S	1
Species Diversity is 74				**Total number of species**	**436**

Crown size: **S** = small (< 3.0 m), **M** =medium (3.0 – 8.0 m) and **L** = large (> 8.0 m)

P=Pioneer NPLD=Non-pioneer light demanders NPSH=Non-pioneer shade bearers

The emergent were dominated by NPLD tree species such as *C. zenkeri, E. angolense, E. ivorense, S. oblonga, P. africanum* and *P. macrocarpa*. However, they also occupied the middle and the understorey (B and C) layers. Similarly, *L. trichilloides* tree species were distributed in B and C layers and *T. tessmanii* was limited to the C-layer whether it had large or narrow crown exposures (Table 7). Probably, the tree species with characteristic large crown that were recorded as having small or medium crown sizes were saplings or pole-sized trees. The shade-bearers that appeared to have very large and extensive crowns may mean that the size is characteristic of the tree or that the gap created supported their growth. Examples of such species were: *C. gabunensis*, *D. klaineana, D. dinklagei, M. barteri, M. acuminata, N. papaverifera, T. discolor*. For all the 436 tree species, individual tree species diversity was 74 and NPLD tree species dominated (42%) followed by NPSH (36%) but P tree species populations was low (22%). Leguminous tree species families however, dominated and constituted about 23% followed by Sterculiaceae and Meliaceae families (each 9.5%).

Hubbell and Foster (1983) stated that species distribution were patchy and closely followed topographic features in Barro Colorado Island in Central Plateau of elevation ranging from 120 to 155 m above mean sea level. In Tinte-Bepo forest in Ghana, slope ranged from 0 to 13 m above mean sea level. The tree species distribution did not however, show any relation to topography. Probably, the topographic range was small to have given rise to tree species differentiation.

The extent, shape and disposition of canopy surface has implications for the distribution of illuminated foliage, the penetration of heat, and the extent of turbulent mixing necessarily constrains some aspects of the internal structure included below that surface. Consequently, changes in the outer canopy reflect the development of the forest (Parker and Russ, 2004). The canopy structure determines the range of traits observed in forest trees and changes the fitness of individual trees. Relationships exist between a mature tree's crown, the structure of adjacent canopy trees, and its own growth rate and mortality. One very noticeable feature of many tree crowns is leaving gaps of varying sizes. These gaps act as a source of sun flecks for understorey species, as a barrier to animal movement (Parker and Russ, 2004).

In this study, smaller gaps were present and did not give rise to many pioneer species recruitment or that the regenerated pioneer species failed to survive under the forest canopy with small gaps. Fairchild (2002) noted that filtering light serves as the driving force for photosynthetic processes, affects all biological and structural aspects of the organism. The limited light availability has induced competition among rainforest plant species for this resource through structural and growth adaptations. He further noted that trees that dominate above the canopy eventually force the other canopy species to grow taller through this competition, thus heightening the canopy. When one canopy tree dies and provides a light gap, many species are quick to fill this "hole" through growth competition for light. Because competition is prominent, a dense canopy's trees typically have their leaves and flowers concentrated at the top of the tree and have very few leaf bearing branches below this point (Whatley and Whatley, 1980). Plant species in a well-developed rainforest must adapt strategies to compete with large canopy trees when a gap is formed in the rainforest canopy.

Between the canopy and forest floor was the understorey of the rainforest. The filtering of light through the crown leaves provides a different light quality and quantity to the understorey trees. Small gaps in a dense forest canopy allow for sun flecks lasting shortly, while larger gaps can allow sun flecks to last for up to 20 mn (Attridge, 1990). Trees that persevere to become part of the canopy exhibit traits of fast primary growth with very little secondary growth. Plants that choose to remain in the understorey or dark forest floor adapt their photosynthetic process or leaf structure and even seed germination. The non-pioneer and shade-bearers encountered in the study plot may have these attributes that ensured their survival and growth. Hence, populations of these two species guilds were high in Tinte-Bepo Forest Reserve.

Farmers usually preserve some tree species when they clear the land. The species which are commonly preserved for their soil enhancing role in the forest zone are largely pioneer species (Amanor, 1996) that can germinate only in gaps and are better adapted to the open farm environment. Only a few non-pioneer light demanders were also reported to be preserved and that they are able to germinate under shade but require gaps in the forest canopy to further develop (Hawthorne, 1993, 1995). Pioneer species often encourage rapid rates of soil nutrient cycling. Owusu-Sekyere *et al* (2003) observed that decomposition of the mixed species leaves litter of a tropical semi-deciduous forest was relatively faster than that of single species. However, Owusu-Sekyere *et al* (2004) reported that leguminous tree species generally decomposed and released nutrients in leaf litter to the soil faster than other leaf types. The non-pioneer species may produce slower nutrient cycling (Amanor, 1996).

One of the purposes of agroforestry tree domestication is the enhancement of stability and productivity of agro-ecosystems by diversifying on-farm tree species composition. Information on landscape-level diversity will assist in targeting tree domestication activities, and will provide benchmark information so that the impacts can be measured (Kindt *et al*, 2001). Agyeman and Kyereh (2006) stated that promoting effective strategies to increase tree diversity in cocoa farms, commercial viability of trees compatible with cocoa must be considered. In different farming systems in the forest zone of Ghana, preservation of trees may be based on several factors. Some trees may be preserved for its extensive crown to provide shade to the companion crop e.g. in cocoa agroforestry. In this case, tree species with characteristic large crowns but tall may be preferred. Others may fix nutrients (nitrogen or phosphorus), thus, legumes and mycorrhizae trees with very narrow crown texture may be preserved. Some trees may be required for fruits, timber, firewood, medicines, fodder and other products or they should not be brittle with branches that easily break and destroy crops, etc. High-quality agroforests depend on natural forests as source habitats for many species (Schroth, 2006).

Tree species have peculiar attributes that make them suitable for integration into different agroforestry systems. There is the need to diversify and increase the production functions of indigenous tree species in different agroforestry faming systems. Indigenous tree species of known characteristics have the potential of diverse use in local agroforestry systems. The trees can be obtained from the natural forest and be useful and beneficial in agroforestry systems combinations. The farmers had observed the trees over the years and have fair knowledge of them. Thus, *Ceiba pentandra, Milicia excelsa* and *Pycnanthus angolensis* have been observed to be compatible with food crops whilst *Ceiba pentandra*, *Terminalia ivorensis, Terminalia superba, Triplochiton scleroxylon* and *Blighia sapida* were considered to restore soil fertility.

They may be locally endorsed for rapid integration into farming systems rather than the introduction of 'alien tree species' that have been given wider publicity but difficult to be accepted by the local farmers.

CHAPTER 5

SUMMARY

5.1 CHAPTER 1 - INTRODUCTION

Wakatsuki *et al*, (1998) hypothesized that lowland areas in inland valleys can be fertilized sufficiently for sustainable "Sawah" rice production if there is bush mature forest growth upland. Nonetheless, because of the pressure on the land, there has been a rapid total conversion of primary forest into scrub, farm-bush and secondary forest. The nutrients recycling within a land use ecosystems of different types of vegetation compositions in the uplands may leach down along the toposequence to influence the lowlands for rice-based cropping systems. The impact of deforestation on biodiversity is a function of environment and the forest type. In all the land uses, i.e. primary and secondary forests and the cocoa plantations, there have been and continue to be anthropogenic and natural disturbances.

Therefore, there was the urgent need to evaluate the various land uses, quantify nutrients being cycled in the primary forest, secondary forest or cocoa plantations and assess nutrients releases to the soil so as to undertake sustainable agroforestry intervention practices and management decisions of the lowlands.

5.2 Chapter 2: MINERAL ELEMENTS COMPOSITION IN LIVING TREES SPECIES OF THE LAND USES IN DWINYAN WATERSHED.

Tinte-Bepo Forest Reserve, a primary forest in Ghana was first constituted in 1949 and now protected under the Forest Protection Law of 1986. Primary forest (Tinte-Bepo Forest Reserve), secondary forests (Akyaakrom, 28 years old) and (Dopiri, 27 years old), and two cocoa plantations (Dopiri and Gold Valley) land uses characterized the Dwinyan Watershed. The Dwinyan River separated the two cocoa plantations.

The bark and leaves samples were collected on 150, 100 and 50 tree species over 5.0 cm dbh in the primary, Akyaakrom and Dopiri secondary forests and cocoa, respectively. There were 26, 20 and 18 different tree species families identified in primary forest, Akyaakrom and Dopiri secondary forests, respectively. Tree populations were 435 in the 0.45 ha, 158 and 118 in 0.19 ha plots in Tinte-Bepo primary forest, Akyaakrom and Dopiri secondary forests, respectively. In terms of tree density and composition, primary forest was higher than Akyaakrom that was superior to Dopiri secondary forest.

Primary forest tree species leaves contained high concentrations of K, Ca, Si, Mg, S, Al and P but lower in Na, Mn and Fe. The tree species leaves contained only trace quantities of Cu, Mo, Sr and Zn. In Akyaakrom secondary forest, the leaves samples elemental concentration in decreasing order was K > Ca > Si > S > Mg > P > Al > Na > Fe > Sr > Mn > Mo > Cu > Zn. Generally, Akyaakrom tree species bark elements concentrations were lower than they were in their leaves and lower than in both leaf and bark samples of the primary forest tree species.

Live tree species leaves from Dopiri secondary forest analyzed indicated that the mean concentrations were in the descending order of Ca > K > Si > Mg > S > P > Na > Al > Fe > Mn > Sr > Mo > Zn > Cu. Analysis result of tree bark samples from Dopiri secondary forest showed that the element concentrations in decreasing order was Ca > K > Si >S > Mg > Al > Na > P > Sr > Fe > Mn > Mo > Cu > Zn. The analysis of the cocoa leaves and barks samples from the two cocoa plantations revealed relatively higher concentrations of Cu but lower concentrations of Mn, Mo, Si, Sr and Zn. The concentration of Ca in the cocoa tree leaves and bark were higher in both plantations. Tree leaves from the primary forest showed high positive correlations with tree samples from the secondary forests and the cocoa plantations.

5.3 Chapter 3: NUTRIENT RELEASE FROM DECOMPOSING LEAF LITTERS FROM THE PRIMARY FOREST, SECONDARY FORESTS and COCOA PLANTATIONS IN DWINYAN WATERSHED.

Litter contains considerable quantities of nutrients necessary for plant growth (Songwe *et al.*, 1995). Soil and forest floor microorganisms and fauna break down and mineralize the litter (Swift *et al.*, 1979). Leaves decompose faster than the other litter types and leaf mineralization is supposed to be rapid. The dried leaf litter for each month was used to identify the tree species of the forests and only cocoa tree leaves were used in both plantations. Mean Monthly litter productions for the two years were used to estimate the annual leaf litter productions for each site.

Four observations on decomposition and nutrient release were carried out from fallen leaf litter of the three land uses tree species. Two sets of observations were carried out on decomposition and nutrient release from freshly the leaves of tree species in the two contrasting secondary forests and the two cocoa plantations. Leaf litter production was highest in the dry season (November to February) in each year. The mean annual leaf litter falls were 8.5 t ha^{-1} for TB, 9.1 t ha^{-1} for AS and 8.9 t ha^{-1} for DS, 7.1 t ha^{-1} for DC and 6.7 t ha^{-1} for GVC during the first year period whilst total amount of rainfall recorded was 1400 mm. The leaf litter fall values obtained for the land uses of Dwinyan Watershed were not significantly different.

Leaf litter production was highest in the dry season in all the land uses. During the major rainy season, leaf fall was the second highest and did not differ between the forests land uses but significant differences at $P > 0.05$ were observed between the forests and the cocoa plantations. Lowest leaf litter fall was observed in the minor rainy season and did not differ between all the land uses. However, significant differences between the seasons and leaf litter productions of the land uses were observed ($P > 0.05$). Leaf litter fall from all the land uses were positively correlated. Conversely, leaf litter fall and rainfall amounts in the seasons were negatively correlated. But leaf litter productions correlation with rainfall amounts in the seasons.

The decomposition of a leaf litter did not dependent on the pattern of monthly rainfall. There was gradual but progressive fragmentation and decomposition of the leaf litter throughout the year. Decomposition of mixed leaf litters differed between Akyaakrom (AM) and Dopiri (DM) secondary forests for the 1st to 3rd and 9th to 10th months. The decomposition of leaf litters from the two cocoa plantations followed similar a trend. Decomposition of Dopiri cocoa leaf litter was relatively slower than Gold Valley.

The concentrations of total extractable polyphenols (TEPH) in each leaf litter type well explained the differences in decomposition rates among leaf litter types. The rapid decline of TEPH in AG caused the rapid decomposition of its leaf litter and the slower decline of TEPH in AM and DA delayed their decomposition. Factors other than TEPH may have contributed to the decomposition in the cocoa leaf litter.

In all the litter types, nutrients were generally released as decomposition progressed. Nutrient releases of K, Mg and P did not differ much between the leaf litter types throughout the decomposition periods. The rate of nutrient release was generally faster than the rate of dry mass loss of a leaf litter during the decomposition especially in its early period.

Generally, nutrient concentrations decreased gradually as the leaf litter decomposed. The leguminous tree *G. simpliciffolia* (AG) decomposed and released nutrient faster than the other leaf litter types. Nutrients releases were prolonged in the leaf litters of the mixed leaves treatments from the two secondary forests. The release of K and Mg in Gold Valley cocoa leaf litter followed the loss of leaf material during decomposition. Generally, cocoa leaves decompose relatively slower.

The pattern of nutrient flux was similar to that of leaf litter production and the residual nutrients. The estimated mean annual nutrient fluxes for the primary forest were 157 kg ha^{-1} yr^{-1} for Ca, 166 kg ha^{-1} y^{-1} for N, 32 kg ha^{-1} y^{-1} for K, 23 kg ha^{-1} y^{-1} for Mg and P was least of 7 kg ha^{-1} y^{-1}. Though, the estimated flux for N did not account for denitrification losses, however, nutrient fluxes in the Tinte-Bepo Reserved primary forest revealed rich nutrient cycling to sustain low levels of soil fertility (Annan-Afful, *et al.*, 2001).

Similarly, estimated nutrient fluxes for each of the secondary forests were: N, 172 and 236 kg ha^{-1}; Ca, 119 and 149 kg ha^{-1}; Mg, 42 and 19 kg ha^{-1}; K, 44 and 13 kg ha^{-1}; and P, 6 and 5 kg ha^{-1} in AS and DS, respectively. The mean annual nutrient fluxes estimated from the two cocoa plantations were: N, 104 and 111 kg ha^{-1}; P, 6.7 and 2.5 kg ha^{-1}; K, 16 and 7 kg ha^{-1}; Ca, 95 and 110 kg ha^{-1}; Mg, 7 and 3 kg ha^{-1} for DC and GVC, respectively. However, the differences in leaf litter production, decomposition trends were related to the leaf characteristics and the nutrient release patterns in each site led to the differences in the amount and patterns of the nutrient fluxes in the forests and the cocoa plantations land uses.

5.4 Chapter 4: INTERGRATED AGROFORESTRY FOR SUSTAINABLE "SAWAH" FARMING SYSTEMS.

The forest canopy elements house the photosynthetic machinery of the forest. In addition, litter from tree contributes to organic matter on the forest floor adding material for the decomposition and energy cycle (Parker, 1994). Trees also play an important role in maintaining the productivity of farming systems. Appropriate agroforestry systems improve soil physical properties, maintain soil organic matter and promote nutrient cycling (Sanchez, 1987).

In Ghana, continuous biodiversity destruction necessitated the re-direction of Ghana's forest policy guidelines on forest conservation. The forestry aspects to integrate into the sawah agricultural technology were to characterize tree species diversity, material and nutrients flow between the land uses most especially, the forest types on the uplands and to encourage the participating communities for reforestation of the degraded parts of the uplands and to diversify income of communities within the framework of Ghana's new forest policy.

The basic information on land title deeds, people and forest use, off-farm activities and possible sources of income apart from farming gathered indicated that individual land ownership was acquired through heritage or by purchase on lease terms. Family land ownerships were encountered and user rights are shared between the family members. The "land owners" were earlier settlers from other parts of the Ashanti Region but now are considered as indigenes. However, there were emigrants from other parts of Ghana outside and within the Ashanti Region. The people in the areas were predominantly food and cocoa farmers and majority of the emigrants were cocoa farms attendants. Most farms owned by the emigrants were either on lease, hire for short periods of 2-3 years or on share-cropping system.

Tree species were found on farmlands indicating that the area is not degraded. But most of the trees that occurred naturally have been preserved for the purposes of soil fertility improvement, wood for construction and household energy, medicines and shade to young cocoa seedlings. Even though the people appreciate and are aware of the value of trees, the culture of tree planting and forest maintenance are ignored.

The ownership rite defined as `all trees belong to the state` and nobody as the right to harvest or use in the existing forest policy is unattractive to planting and protecting timber and other high valued economic tree species. Legally constituted permanent forest reserves forms 11 % of the total 16 % forestland area of Ghana. The earlier forest policy in Ghana had been to progressively utilize the forest resources without replacement, prior to their destruction by conversion to other forms of land use. The reckless uses of the forestlands have reduced the entire forest estate to mere relics of vegetation. However, the revised policy attempts to promote, involve and recognize the contributions of individuals, communities, organizations and local authorities to effectively conserve and develop the forest resources for optimum benefit from their utilization.

Trees can be referred to as ecological engineers and the watershed is comprised of drainage axes that seepage and runoff from adjacent lands converge. Therefore, the dissolved nutrients would impact on fertility status of inland valley bottoms and runoff and rainwater from the upland would move vertically and laterally into valley bottoms for various cropping systems e.g. *Sawah* rice and vegetables.

All the trees species guilds showed both large and smaller crowns and could be found in all the layers of the canopy. Populations and diversities of the pioneer tree species were low whilst that of non-pioneer light demanders were highest followed by the shade-bearers. The architectures, physiognomies and textures of the crowns were different for all the individual tree species within and between guilds. Agroforestry trees domestication activities will impact positively on local farmers if local indigenous tree species of known characteristics are used and have the potential to be accepted for the different local agroforestry systems combinations on farmlands.

For the Sawah rice in the valley bottoms, there is the need to integrate some form of agroforestry in the uplands. The primary forest recycles and releases nutrients better than the secondary forest and the cocoa plantation. Conservation of the forest to continue providing the much needed ecosystem services to the sawah system cannot be guaranteed. It will be cleared to establish farms or at least there will be trees removal either for timber or for firewood. Thus, the forest will be under constant influence by man. The cocoa plantation always has tree species in association and can be provide the forest cover. The best option is to establish cocoa agroforest from the fringes of the sawah to a reasonable part on the upslope. Cocoa trees require shade. Trees of economic value should be selected for the cocoa agroforest to diversify income sources and improve living conditions of the farmers. From the results of this study, cocoa agroforestry is recommended for integration into the sawah ecosystem.

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Abbreviations used

Anac = Anacardiaceae	Anno = Annonaceae	Apoc= Apocynaceae
Bign = Bignoniaceae	Bomb = Bombaceae	Caes= Caesalpiniaceae
Comb = Combretaceae	Conn= Connaraceae	Euph= Euphorbiaceae
Gutt = Guttiferae	Laur = Lauraceae	Loga = Loganiaceae
Melas= Melastomaceae	Meli = Meliaceae	Mimo= Mimosaceae
Mora= Moraceae	Myris = Myristicaceae	Olac = Olacaceae
Pand = Pandaceae	Papi= Papilionaceae	Rham = Rhamnaceae
Rubi = Rubiaceae	Ruta = Rutaceae	Sapin = Sapindaceae
Sapo = Sapotaceae	Sima = Simaroubaceae	Sterc = Sterculiaceae
Tili = Tiliaceae	Ulma = Ulmaceae	

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2. **Owusu-Sekyere, E**, Cobbina, J and Wakatsuki, T. 2006. Nutrient cycling in Primary, secondary and Cocoa Plantations in Ashanti Region, Ghana. *West African Journal of Applied Ecology*. Vol. 9. Pp131-140.
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Appendix A: Rainfall (mm) in Asuadei and Potrikrom towns for the Dwinyan watershed from January 1998 to December 2000.

Asuadei	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1998	0.0	18.2	24.1	224.4	168.0	210.7	109.5	253.2	280.2	143.2	126.7	134.9
1999	32.4	17.2	105.3	204.5	97.8	294.6	85.4	87.1	331.8	143.2	104.0	0.0
2000	0.0	0.0	82.6	137.0	181.1	163.7	177.3	207.9	138.7	150.4	63.7	0.0
Potrikrom	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1998	55.1	62.0	14.9	252.3	179.0	134.0	76.4	164.8	175.5	194.1	36.5	69.5
1999	17.2	53.7	165.4	275.7	62.0	247.5	224.4	66.2	182.8	112.1	90.0	0.0
2000	0.0	0.0	90.4	132.8	156.9	225.9	127.7	153.5	125.6	144.6	87.8	0.0

Appendix B: Inventory and total element concentrations (mg kg^{-1}) of leaves of tree species in Tinte-Bepo Reserved Primary Forest (T-BFR)

Tree No	Local Name	Scientific Name	Family Name	Element (mg kg^{-1})													
				Na	**K**	**S**	**Al**	**Ca**	**Cu**	**Fe**	**Mg**	**Mn**	**Mo**	**P**	**Si**	**Sr**	**Zn**
84	esakokoo	*Celtis zenkeri*	Ulma	672.4	12709.5	1585.8	696.4	12530.7	17.8	523.1	3896.0	161.0	53.9	1481.6	4614.2	97.1	17.2
85	dwedwedwedwe	*Dialium dinklagei*	Caes	446.1	5179.4	4303.1	13867.9	11332.6	13.4	296.0	2568.8	722.8	59.8	938.3	3973.7	83.6	17.5
88	ntwesono	*Aulacocalyx jasminiflora*	Rubi	1325.7	16853.8	1764.8	666.5	12557.8	18.6	223.7	10016.1	2011.9	101.2	1255.2	3697.3	140.9	9.8
89	odwono	*Baphia nitida*	Papi	756.5	14443.8	2313.8	550.6	5058.0	16.8	222.5	2520.3	790.7	44.5	1518.0	3987.3	29.4	31.3
90	anansedodowaa	*Cola millenii*	Sterc	1072.0	6336.1	1487.5	715.3	8858.3	22.7	287.4	4466.1	761.1	62.5	1145.1	7257.0	74.7	13.3
91	nyankomanini	*Myrianthus libericus*	Mora	848.0	9751.6	2288.3	775.5	7533.3	23.9	327.9	4074.7	116.7	64.3	690.3	20483.6	81.1	13.1
92	fotie/hotrohotro	*Anthocleista nobilis*	Loga	611.8	9256.8	2580.1	573.5	7428.9	19.6	223.0	6889.4	62.1	95.4	972.4	6686.6	25.0	13.7
94	funtum	*Funtumia elastica*	Apoc	493.9	13832.0	1120.2	571.9	11386.0	21.5	167.1	2986.7	369.2	55.3	985.2	16328.9	117.8	20.7
95	esakokoo	*Celtis zenkeri*	Ulma	603.8	11501.8	1941.2	388.7	3421.9	18.6	157.9	1895.5	385.2	51.4	1114.3	3908.6	19.8	22.8
111	odwono	*Baphia nitida*	Papi	535.7	13778.8	4719.4	1085.7	28146.6	17.6	263.2	10881.9	154.9	108.2	1239.3	9845.7	262.1	26.0
112	kaakaadikro	*Trichilia prieuriana*	Meli	612.9	12042.2	4769.5	644.6	13225.0	29.5	164.8	6101.3	711.6	66.6	1308.8	7014.6	103.4	17.4
113	dubinkokoo	*Khaya ivorensis*	Meli	469.9	9088.3	2119.3	747.3	10667.8	14.0	243.4	3938.2	81.5	51.0	737.7	6028.5	97.8	22.2
114	dubinbre	*Lovoa trichilloides*	Meli	532.0	6490.4	3112.4	908.5	14727.6	20.2	259.6	4383.5	202.1	64.7	761.6	5227.2	143.7	27.5
115	motokrodua	*Monodora tamifolia*	Anno	427.7	9964.4	4925.4	475.5	6284.2	18.6	175.4	2401.0	684.6	47.2	771.2	3629.0	27.5	14.2
122	otwese	*Memecylon lateriflorum*	Melas	959.2	15566.3	3598.1	629.2	8993.1	14.5	333.2	2299.1	1257.1	31.7	706.0	11769.9	44.9	11.1
123	tanuro	*Trichilia monadelpha*	Meli	174.2	19564.3	103.6	12333.8	1657.8	622.0	3087.3	6977.3	3099.0	0.0	3378.6	0.0	616.7	622.1
124	pobe	*Massularia acuminata*	Rubi	1274.7	387755.2	1778.2	1027.8	27960.7	20.3	189.2	4391.9	912.5	50.5	953.7	26494.5	235.1	18.0
125	pobe	*Massularia acuminata*	Rubi	1356.6	9421.7	1778.2	1027.8	27960.7	20.3	189.2	4391.9	912.5	50.5	953.7	26494.5	235.1	18.0
126	danta	*Nesogordonia papaverifera*	Sterc	587.3	13613.9	1560.5	729.1	5944.1	21.8	198.1	2520.1	71.5	37.6	785.3	3902.4	64.1	23.5
127	otwese	*Memecylon lateriflorum*	Melas	1264.0	14470.4	1995.5	517.5	3017.6	15.5	363.8	1757.1	254.5	41.1	1705.3	3465.7	19.4	21.3
128	kaakaadikro	*Trichilia prieuriana*	Meli	586.8	5899.9	2130.8	534.8	6414.1	14.6	278.2	1998.6	1112.4	34.1	1422.4	3413.8	38.6	29.8
129	afena	*Strombosia glaucescens*	Olac	572.8	5998.3	1172.4	610.0	10042.7	14.0	201.4	1581.7	413.5	39.4	636.0	3236.0	39.8	11.5
130	fema	*Microdesmis puberula*	Pand	657.6	12065.8	1564.3	379.2	6736.1	14.0	126.5	3539.6	36.2	97.8	953.0	3015.0	59.5	20.4
131	kyereye	*Pterygota marcrocarpa*	Sterc	427.5	5350.4	3823.4	589.0	10125.9	14.2	223.9	2490.9	723.5	42.5	789.8	7825.8	79.6	10.9
133	esakokoo	*Celtis zenkeri*	Ulma	438.9	7272.4	1827.7	701.2	13562.2	20.4	402.8	3853.9	961.1	57.9	1148.6	15403.7	115.9	17.3
134	pampenama	*Corynanthe pachyceras*	Rubi	445.6	5736.7	4772.4	891.8	13680.2	16.7	367.1	3640.2	1512.6	52.5	756.0	4784.3	47.9	18.7
135	odwono	*Baphia nitida*	Papi	366.2	8476.5	1658.9	641.8	8973.2	18.5	268.6	2858.2	85.4	46.0	709.7	3105.6	92.3	35.7
136	odwono	*Baphia nitida*	Papi	864.5	8897.7	2182.1	341.3	4216.6	16.2	179.1	2754.7	179.5	41.9	1044.6	6304.2	41.8	19.3
138	duabankye	*Dialium aubrevillei*	Caes	661.8	12613.7	1545.6	728.3	16878.0	23.8	196.4	8475.8	900.8	91.4	1340.6	4315.2	194.3	17.6
139	edinam	*Entandrophragma angolense*	Meli	495.3	10570.8	2237.0	522.3	5883.3	18.3	229.1	3497.9	963.5	56.9	1581.2	3707.8	25.0	25.1

144	fema	*Microdesmis puberula*	Pand	958.5	10932.6	2367.1	694.0	14246.2	20.5	254.5	2481.9	58.8	60.4	565.3	14949.5	147.8	1.1
145	odwono	*Baphia nitida*	Papi	1102.8	11076.2	2245.9	478.0	5776.1	16.3	182.2	1848.4	658.7	43.6	1065.9	3071.5	33.9	15.5
146	afena	*Strombosia glaucescens*	Olac	377.7	3471.7	6485.3	520.3	6505.1	20.0	237.8	1475.7	1508.8	47.2	975.7	4902.2	25.8	6.2
148	pampenama	*Corynanthe pachyceras*	Rubi	428.3	6162.3	2409.5	1128.0	26947.3	12.3	250.2	6472.6	96.6	95.1	574.6	6607.9	126.5	5.4
149	bese	*Cola nitida*	Sterc	959.2	13667.1	2267.5	842.2	20394.8	14.8	220.0	3810.8	65.7	59.5	620.1	5937.4	73.8	11.2
150	kyereye	*Pterygota marcrocarpa*	Sterc	538.7	7558.8	6845.9	960.7	19328.3	31.2	321.3	5647.2	178.5	84.7	1123.3	4193.4	142.9	12.2
151	kaakaadikro	*Trichilia prieuriana*	Meli	825.7	6745.8	1880.1	470.7	5790.5	20.6	230.8	4601.2	485.9	68.5	1295.7	4831.3	34.0	14.1
152	odwono	*Baphia nitida*	Papi	323.8	3864.6	3966.8	818.0	16207.5	19.6	215.1	4283.4	95.6	70.9	738.2	7188.3	173.9	10.3
153	dubinbre	*Lovoa trichilloides*	Meli	425.1	4320.4	2633.9	641.6	12133.7	12.3	224.4	5334.7	84.7	68.7	669.4	15684.0	85.8	5.7
154	okure	*Trilepisium madascariense*	Mora	413.9	16114.3	2656.1	582.2	6857.6	19.6	256.1	3856.4	561.9	64.9	556.5	12409.6	69.5	3.9
155	odwono	*Baphia nitida*	Papi	662.3	10347.4	1669.1	454.6	7789.4	23.4	176.0	1229.5	79.3	43.8	755.3	3572.7	86.2	18.5
156	duade	*Craterispermum caudatum*	Rubi	867.7	11454.0	1541.2	418.7	5082.7	27.0	184.2	1376.6	82.7	49.4	774.4	3732.8	42.5	25.0
157	dubinbre	*Lovoa trichilloides*	Meli	530.4	11810.4	1383.0	538.4	8248.9	20.1	206.8	3491.6	358.3	66.1	651.8	3848.1	41.5	6.1
158	dubinbre	*Lovoa trichilloides*	Meli	597.4	7309.7	2316.6	1006.5	24378.9	27.6	256.4	5350.0	894.5	84.1	784.4	28681.0	222.1	17.0
159	dwendweraa	*Lecaniodiscus cupanioides*	Sapin	486.2	6947.9	2525.6	415.7	6279.1	23.9	167.2	4318.4	268.7	89.5	893.7	7125.6	55.8	20.6
161	anansedodowaa	*Cola millenii*	Sterc	801.1	5603.7	2245.4	695.9	12023.6	21.7	198.3	4582.2	82.1	69.2	791.1	5772.1	101.1	14.7
162	duasika	*Enantia polycarpa*	Anno	729.4	14975.8	3186.4	575.1	8452.3	22.3	240.3	3122.5	673.2	67.2	597.4	6998.3	36.9	14.4
163	sopi	*Daniellia thurifera*	Caes	965.6	2485.0	1058.6	411.8	4489.4	20.6	218.3	1211.7	62.2	51.7	522.5	4690.4	34.8	18.0
165	duawisa	*Isolona campanulata*	Anno	574.6	3071.2	3014.8	428.6	7872.6	6.0	300.9	1822.6	63.8	20.6	533.2	2756.2	52.2	1.0
166	pampenama	*Corynanthe pachyceras*	Rubi	791.2	10830.0	1655.0	29054.8	16519.7	7.7	198.2	4531.8	2079.4	116.3	465.9	3928.4	248.1	8.7
168	pampenama	*Corynanthe pachyceras*	Rubi	594.2	6463.8	4855.9	732.1	12740.2	9.9	259.9	2747.8	823.8	32.7	528.2	7970.2	69.5	4.4
170	sonkyi	*Allanblackia parviflora*	Gutt	347.9	14912.0	2431.6	374.8	5268.7	11.0	169.9	4150.3	257.3	45.9	746.6	7369.2	47.0	9.5
171	esakokoo	*Celtis zenkeri*	Ulma	577.2	22668.5	3347.4	276.3	3633.1	20.2	164.5	2398.8	1014.5	34.2	1436.0	3773.3	18.1	45.6
174	bese	*Cola nitida*	Sterc	701.7	8400.3	2064.2	662.8	5531.6	8.1	180.3	1781.5	623.2	23.5	975.3	2716.5	33.6	26.4
175	bese	*Cola nitida*	Sterc	724.6	14012.9	3194.2	338.1	5936.7	13.9	174.5	1457.1	1143.8	27.0	906.3	6479.1	54.1	9.1
176	motokrodua	*Monodora tamifolia*	Anno	850.1	5623.2	2371.5	326.2	6403.7	12.4	138.9	4700.6	232.2	53.0	957.0	4775.0	54.7	13.6
177	pampenama	*Corynanthe pachyceras*	Rubi	818.2	11539.1	3594.2	593.4	5917.4	27.9	373.0	4987.1	492.9	55.2	741.2	10273.7	56.3	17.5
178	duade	*Craterispermum caudatum*	Rubi	523.5	5217.3	3825.6	722.8	12043.4	10.6	310.6	9379.8	94.1	94.8	781.9	12357.9	46.3	4.8
179	duade	*Craterispermum caudatum*	Rubi	546.9	3231.4	2912.4	492.7	9436.9	11.5	189.3	3585.0	260.9	45.3	909.9	3745.0	51.3	6.1
180	fema	*Microdesmis puberula*	Pand	837.9	11315.6	1891.7	27054.6	15544.9	10.3	212.1	4327.7	1148.5	120.4	503.9	3876.8	245.7	10.3
181	bese	*Cola nitida*	Sterc	768.7	7421.4	1594.7	472.6	8380.5	15.3	181.3	2481.4	85.2	38.1	573.0	3559.3	74.5	22.7
182	odwono	*Baphia nitida*	Papi	607.4	12661.6	2044.5	537.7	24660.6	20.9	314.7	2438.7	82.6	37.8	690.4	3828.8	91.9	36.2
183	odwono	*Baphia nitida*	Papi	724.4	8192.8	2711.0	885.3	20869.4	12.3	318.7	5858.7	159.1	67.6	1126.3	4265.9	214.0	20.7
186	hwenteaa	*Xylopia aethiopica*	Anno	1156.7	13078.3	804.4	334.0	5799.4	13.1	115.3	2556.1	18.3	30.0	654.9	2829.3	48.7	5.6

187	odwono	*Baphia nitida*	Papi	463.9	12959.5	5658.3	506.3	7371.1	19.0	220.5	1603.5	532.0	19.2	1224.3	5053.4	23.6	16.8
188	pampenama	*Corynanthe pachyceras*	Rubi	404.9	5963.7	2990.1	562.5	9476.4	10.2	230.6	7509.4	58.3	114.7	879.1	9425.1	30.0	8.6
189	duawisa	*Isolona campanulata*	Anno	363.5	7049.0	1227.3	629.5	13939.3	10.5	180.7	5886.1	304.4	59.4	1024.8	3272.4	109.1	15.3
190	fotie/hotrohotro	*Anthocleista nobilis*	Loga	781.2	4526.4	2353.7	446.6	7540.3	12.9	231.9	1932.7	1527.1	20.7	1010.8	6371.7	77.5	13.1
193	esakokoo	*Celtis zenkeri*	Ulma	749.6	13433.0	1695.8	34838.6	17392.5	15.3	283.4	6306.9	1800.0	125.3	812.4	4084.4	300.8	13.4
194	duade	*Craterispermum caudatum*	Rubi	681.3	12718.6	1646.1	800.7	15299.1	14.6	237.3	4851.1	532.5	50.5	1215.1	9175.2	124.8	16.4
195	pampenama	*Corynanthe pachyceras*	Rubi	875.1	9022.7	1427.5	356.7	4824.8	13.7	169.0	1603.3	47.2	18.1	819.5	3044.8	49.9	30.5
197	pampenama	*Corynanthe pachyceras*	Rubi	890.6	21210.8	2477.6	425.1	5147.0	17.7	221.6	1959.0	811.9	25.5	1031.4	12980.7	18.8	21.2
198	nwama	*Ricinodendron heudelotii*	Euph	444.6	11810.4	1937.8	760.2	14160.5	13.3	213.9	11273.8	2857.8	99.5	1108.8	4226.8	152.2	6.5
199	ohaa	*Sterculia oblonga*	Sterc	545.8	18769.0	2565.0	434.7	7177.4	11.4	182.7	5323.2	993.5	48.6	894.3	2702.0	46.9	28.7
200	esakokoo	*Celtis zenkeri*	Ulma	732.0	6910.7	4186.0	428.7	6769.0	9.5	247.2	1720.0	794.0	30.1	850.1	5958.7	56.0	4.7
201	duade	*Craterispermum caudatum*	Rubi	349.5	7373.5	1752.7	505.3	8015.0	19.3	211.2	5883.6	842.0	57.1	1401.9	6102.7	69.5	26.1
203	fotie/hotrohotro	*Anthocleista nobilis*	Loga	777.3	7315.0	1066.8	340.5	3756.9	17.1	167.7	1338.2	26.7	17.2	758.3	3603.7	45.3	17.6
204	funtum	*Funtumia elastica*	Apoc	571.9	9927.1	2111.2	470.2	5871.6	17.9	228.3	3741.0	270.3	40.5	1016.7	7639.0	50.3	16.1
205	odwono	*Baphia nitida*	Papi	496.7	12745.2	1588.8	542.9	6416.6	16.2	396.2	3031.1	30.5	39.0	1416.9	5885.6	62.6	20.4
206	duade	*Craterispermum caudatum*	Rubi	499.5	6575.5	3633.4	583.4	9167.5	8.9	266.8	1585.6	506.9	21.5	558.9	5533.9	65.8	7.8
207	esakokoo	*Celtis zenkeri*	Ulma	513.4	7916.2	4318.1	758.2	15128.7	15.2	206.9	2499.8	1545.8	31.6	1062.6	11408.3	208.1	16.7
209	pampenama	*Corynanthe pachyceras*	Rubi	495.6	8534.2	2209.5	923.1	14407.9	13.6	443.1	3702.3	90.9	36.9	1104.1	7424.8	116.8	20.6
212	bese	*Cola nitida*	Sterc	590.9	14440.0	1586.3	401.2	6319.3	19.8	283.7	3954.4	757.8	42.8	1476.2	5090.2	43.6	20.1
213	ntwesono	*Aulacocalyx jasminiflora*	Rubi	1048.9	11309.4	1702.7	514.4	8480.8	18.5	238.2	3369.7	480.9	35.9	1119.9	17735.5	65.0	13.0
214	pobe	*Massularia acuminata*	Rubi	866.6	7804.4	4654.9	670.1	12051.0	13.4	257.4	2849.2	672.7	32.1	805.9	8359.3	68.1	9.2
215	fema	*Microdesmis puberula*	Pand	856.5	15332.2	1193.4	379.9	5833.1	18.9	196.1	1826.9	45.5	23.0	836.8	4004.1	39.4	22.5
216	motokrodua	*Monodora tamifolia*	Anno	910.3	15076.9	1642.3	672.1	14809.1	21.9	207.2	2304.4	295.6	24.2	1087.5	13279.2	123.6	13.5
217	pampenama	*Corynanthe pachyceras*	Rubi	666.3	4606.2	1210.9	306.9	3828.6	16.4	204.1	1127.4	28.1	14.6	1201.0	3250.7	28.7	42.4
219	bese	*Cola nitida*	Sterc	526.1	13316.0	1750.6	470.1	10633.0	13.2	113.2	3998.1	14.2	37.6	1096.1	3568.7	88.2	18.7
220	otwese	*Memecylon lateriflorum*	Melas	535.2	6134.0	941.7	4027.9	4308.1	14.6	123.3	1955.5	161.1	26.4	780.8	3490.5	49.7	20.9
222	ntwesono	*Aulacocalyx jasminiflora*	Rubi	340.9	6796.3	1879.1	592.1	15068.2	20.2	171.0	5316.4	881.0	52.2	1518.0	6567.2	123.1	20.1
223	odwonkobire	*Baphia pubescens*	Papi	407.5	16183.4	2238.6	1124.9	19647.7	15.3	410.2	3053.1	254.2	32.6	1000.3	11204.2	182.9	7.7
224	ntwesono	*Aulacocalyx jasminiflora*	Rubi	608.3	4690.5	1569.7	600.8	13571.3	18.3	239.6	2997.4	480.6	32.5	993.2	20643.2	113.4	10.2
225	duabankye	*Dialium aubrevillei*	Caes	580.3	8494.3	1388.8	514.2	8919.0	15.5	254.2	5961.7	536.3	56.6	1311.8	4059.6	33.7	13.3
226	esakokoo	*Celtis zenkeri*	Ulma	396.3	7860.3	1332.4	390.4	5629.8	17.8	144.5	1582.8	43.5	21.5	794.6	3695.5	49.8	30.5
227	fema	*Microdesmis puberula*	Pand	462.8	15082.2	4608.9	927.5	17485.8	19.7	289.1	4826.2	80.5	46.4	915.2	3855.5	202.1	33.9
228	pampenama	*Corynanthe pachyceras*	Rubi	931.9	10418.3	5095.9	849.5	15101.8	11.7	297.3	2977.2	535.4	39.5	642.5	9594.0	57.8	10.1
230	esakokoo	*Celtis zenkeri*	Ulma	807.6	8996.1	5316.3	747.1	13086.0	14.9	268.1	2222.2	2092.1	28.2	915.2	7027.3	60.4	15.0

231	pampenama	*Corynanthe pachyceras*	Rubi	349.8	11801.5	1538.5	816.6	13736.2	17.1	391.9	3663.0	338.2	37.9	884.8	27145.0	144.7	11.4
232	edinam	*Entandrophragma angolense*	Meli	460.7	7607.6	1262.3	424.9	6498.0	10.0	213.1	2185.9	50.7	14.1	771.2	2183.3	76.0	21.6
233	pampenama	*Corynanthe pachyceras*	Rubi	507.3	5764.6	2282.8	339.0	6716.7	7.3	151.1	4199.6	215.8	56.5	909.8	6154.4	93.7	12.1
235	anansedodowaa	*Cola millenii*	Sterc	930.5	7075.6	3631.3	22671.4	16451.3	14.3	246.8	5355.0	827.5	90.7	1057.5	3281.1	166.3	33.5
236	tanuro	*Trichilia monadelpha*	Meli	589.2	3961.2	8744.5	572.1	11877.8	28.7	185.6	2594.6	722.6	24.0	773.4	11875.0	119.8	68.9
237	esakokoo	*Celtis zenkeri*	Ulma	418.8	8800.8	1588.7	650.3	11230.2	6.7	277.2	5630.2	242.6	56.9	795.3	4086.7	118.5	12.2
238	hyedua	*Daniella ogea*	Caes	839.5	4722.0	1523.0	404.6	6881.0	14.3	200.0	1505.8	29.3	14.6	694.6	2886.6	74.8	24.1
239	pampenama	*Corynanthe pachyceras*	Rubi	823.3	14022.6	1399.6	673.2	8489.1	13.9	271.7	1876.1	53.6	21.2	793.7	8517.8	49.5	5.8
240	potrodom	*Erythrophleun ivorense*	Caes	390.6	9363.2	4594.1	12670.6	5049.0	21.4	150.2	2639.7	417.2	50.8	1687.1	3414.6	29.3	12.1
244	pobe	*Massularia acuminata*	Rubi	713.3	4262.2	1631.8	691.5	18452.7	11.0	153.4	2723.0	24.0	38.1	1317.0	5521.8	121.7	7.9
245	fema	*Microdesmis puberula*	Pand	492.1	13470.2	2171.3	28731.1	16520.5	12.2	347.3	4763.1	1231.5	102.3	829.4	4536.5	293.5	16.7
246	esakokoo	*Celtis zenkeri*	Ulma	552.2	5165.7	2113.2	360.4	3945.7	14.0	232.3	1303.2	355.8	28.4	1569.5	3844.9	23.1	32.4
247	pampenama	*Corynanthe pachyceras*	Rubi	798.0	9097.2	6973.2	15470.1	14239.8	15.6	248.9	3662.7	523.3	64.9	1216.5	4027.1	86.9	18.6
248	bese	*Cola nitida*	Sterc	1000.2	9783.5	1929.6	561.4	11683.8	10.3	179.0	1821.6	1040.3	20.7	861.0	7445.2	71.4	12.8
249	apotrowa	*Maesobotrya barteri*	Euph	332.5	5825.4	2513.1	844.1	20953.7	14.0	290.3	9386.0	266.4	80.0	1662.3	3748.8	213.8	24.1
251	motokrodua	*Monodora tamifolia*	Anno	528.9	19311.6	3211.9	322.9	6197.0	12.0	172.2	1454.1	0.4	13.0	910.1	2940.8	36.6	0.5
252	funtum	*Funtumia elastica*	Apoc	433.6	3803.3	2058.1	704.3	12822.9	14.1	171.8	9320.2	2497.7	80.1	934.7	3663.4	130.1	5.5
253	pampenama	*Corynanthe pachyceras*	Rubi	727.1	10427.2	1457.2	578.9	13936.6	7.8	283.3	2009.8	15.7	24.2	982.4	23954.4	42.4	3.2
256	totro	*Anthonotha macrophylla*	Caes	702.8	14715.1	2630.4	345.1	5646.6	13.2	275.6	3322.9	592.7	68.7	907.7	4190.6	21.0	9.0
257	dwedwedwedwe	*Dialium dinklagei*	Caes	563.9	5021.5	2612.9	654.3	16222.7	13.8	162.7	3699.4	39.3	34.3	1175.8	3819.6	174.8	35.7
259	dubinkokoo	*Khaya ivorensis*	Meli	443.7	5548.8	1523.9	729.4	18491.5	11.9	225.9	2886.2	536.0	24.7	1104.5	4099.6	199.4	8.8
260	duade	*Craterispermum caudatum*	Rubi	598.1	7778.6	3291.3	934.1	21954.3	8.4	426.2	4760.3	1004.7	56.4	1022.6	10544.5	261.8	9.4
261	odwono	*Baphia nitida*	Papi	393.7	4548.6	1721.7	206.2	3447.6	13.5	112.8	2834.0	337.6	28.8	1871.8	3009.8	28.2	18.9
262	pampenama	*Corynanthe pachyceras*	Rubi	675.2	6051.5	1484.4	444.3	8330.9	7.7	131.7	890.0	0.0	10.5	685.5	4099.0	26.8	10.2
263	afena	*Strombosia glaucescens*	Olac	839.5	8942.9	1449.7	365.4	7232.8	14.9	162.3	4269.7	755.7	41.4	1327.1	5941.2	73.9	11.6
265	nwama	*Ricinodendron heudelotii*	Euph	500.1	10882.7	5046.6	5621.6	7206.5	11.8	218.6	2187.5	270.2	28.9	1024.0	3374.8	44.7	10.3
266	denya	*Cylicodiscus gadunensis*	Mimo	423.9	3601.0	2748.5	356.0	5693.3	9.0	199.6	2515.0	394.7	21.8	1452.1	3457.9	51.2	10.7
268	ntwesono	*Aulacocalyx jasminiflora*	Rubi	541.6	3850.6	1140.0	330.5	6856.8	5.6	116.2	3969.7	266.7	34.6	729.0	2338.1	50.9	9.6
269	bonsamdua	*Disthemonanthus bentamianus*	Caes	384.8	15543.3	2271.1	986.8	23124.9	5.6	189.4	5738.3	108.2	50.3	664.4	9676.4	139.3	12.9
270	akye	*Blighia sapida*	Sapin	455.9	2923.3	4520.4	1058.1	25475.4	16.4	356.7	4777.4	78.1	85.0	1572.6	2616.9	375.9	67.7
271	kaakaadikro	*Trichilia prieuriana*	Meli	337.1	4575.2	2304.9	1220.9	30398.0	6.4	263.8	5760.0	17.3	51.4	645.0	8363.7	158.7	25.4
272	ohaa	*Sterculia oblonga*	Sterc	511.8	9799.4	2378.0	1497.9	0.0	12.9	331.1	7103.6	119.4	61.1	802.0	7206.4	78.6	18.2
273	pobe	*Massularia acuminata*	Rubi	1461.4	4833.8	1467.5	567.5	8810.3	6.8	250.8	2125.6	1459.8	22.7	1080.9	3900.6	44.0	24.6
274	anansedodowaa	*Cola millenii*	Sterc	706.0	27291.6	2294.7	595.4	13179.2	25.9	185.0	3294.4	759.2	34.7	1058.8	10871.8	100.8	21.8

275	pobe	*Massularia acuminata*	Rubi	660.6	13091.6	2230.3	190.0	2613.0	10.2	291.3	4009.4	4.5	40.6	1380.2	6386.7	4.3	2.2
276	anansedodowaa	*Cola millenii*	Sterc	740.0	14135.2	2486.3	874.9	12655.7	17.6	382.8	2948.9	184.4	31.7	884.7	4525.2	144.4	5.7
277	kaakaadikro	*Trichilia prieuriana*	Meli	435.2	10815.6	1879.2	908.9	9143.0	10.2	515.5	3896.6	335.1	41.7	860.5	4750.8	78.2	13.0
278	dwendweraa	*Lecaniodiscus cupanioides*	Sapo	990.1	14949.2	1606.8	394.2	6101.8	13.0	201.8	3180.9	366.2	34.6	1135.4	3669.7	28.2	9.3
279	funtum	*Funtumia elastica*	Apoc	847.5	9948.4	2069.5	394.4	6896.0	3.1	331.6	6020.9	11.3	47.6	690.2	6235.6	26.9	2.2
280	otwese	*Memecylon lateriflorum*	Melas	390.0	17603.9	1450.7	633.5	15308.5	7.1	196.7	1563.0	553.1	10.9	1144.9	3218.1	59.7	13.4
293	kaakaadikro	*Trichilia prieuriana*	Meli	349.0	6091.4	4859.2	697.9	16603.7	14.4	174.5	5406.9	105.0	44.0	1901.0	5643.3	97.9	12.6
294	tanuronini	*Trichilia tessmanii*	Meli	765.0	16555.8	2925.1	362.7	6010.0	9.2	209.5	2575.2	124.3	18.5	1164.4	3079.9	36.4	8.1
295	tanuronini	*Trichilia tessmanii*	Meli	444.2	18726.4	2866.3	417.8	4585.5	8.6	202.5	1853.8	232.9	12.7	1750.1	4286.6	36.2	11.2
296	odwono	*Baphia nitida*	Papi	664.5	7479.9	1553.0	1550.7	7388.6	7.7	350.9	2301.5	1210.6	20.1	908.5	3494.4	60.8	25.0
297	bese	*Cola nitida*	Sterc	578.8	6394.6	4386.9	613.2	13395.8	11.3	210.5	1776.8	629.5	18.8	665.8	10001.8	45.0	3.9
298	nakwa	*Holoptelea grandis*	Ulma	357.8	6375.1	3406.9	8787.9	8836.7	9.5	190.7	2741.2	332.7	48.9	1137.3	4310.3	48.1	7.0
300	pobe	*Massularia acuminata*	Rubi	376.8	4028.1	1025.9	1126.9	12183.4	7.3	172.7	3818.7	302.0	34.9	525.1	3153.7	87.7	10.8
301	funtum	*Funtumia elastica*	Apoc	382.2	4788.0	1240.2	754.2	12228.2	9.8	347.8	5269.5	571.0	49.5	961.5	5327.5	127.3	7.3
304	funtum	*Funtumia elastica*	Apoc	782.5	5023.0	1511.2	781.2	13251.0	5.5	272.8	5290.4	301.1	55.2	765.1	4058.3	102.2	21.4
308	fotie/hotrohotro	*Anthocleista nobilis*	Loga	547.4	6469.1	1732.0	434.6	10036.2	10.6	156.5	2574.9	305.3	24.4	759.0	3610.2	79.1	14.0
387	dahoma	*Piptadeniastrum africanum*	Mimo	607.4	9358.8	2387.0	576.1	11645.1	9.6	212.9	3893.2	736.6	37.4	1316.2	7780.6	112.7	33.8
388	wawa	*Triplochiton scleroxylon*	Sterc	439.3	8937.6	1535.2	865.9	21223.9	8.0	177.3	3496.4	163.7	32.4	744.8	12811.0	191.3	7.6
389	akyebire	*Blighia welwitschii*	Sapin	641.6	34750.2	1926.9	846.1	9986.1	16.0	87.9	3637.2	1254.8	33.0	1213.8	2981.9	94.6	21.9
390	funtum	*Funtumia elastica*	Apoc	440.0	6639.4	1510.1	357.6	4020.1	5.2	310.0	1288.1	537.4	17.0	1302.3	3984.8	16.1	22.8
392	pobe	*Massularia acuminata*	Rubi	527.7	13587.3	2508.8	405.8	6176.8	14.5	188.2	5179.4	1714.3	53.7	722.9	3606.1	72.5	5.1
393	fema	*Microdesmis puberula*	Pand	742.1	2218.8	2967.1	464.2	6013.2	10.6	282.3	2976.1	69.6	28.2	832.4	3627.8	72.2	2.4
394	dwedwedwedwe	*Dialium dinklagei*	Caes	1223.2	21989.3	1644.8	14401.3	7461.5	9.2	267.2	2545.5	260.0	54.5	774.6	3392.6	78.4	19.9
395	sonkyi	*Allanblackia parviflora*	Gutt	655.4	17896.5	6795.3	812.7	15066.8	12.1	378.1	3256.0	927.1	33.4	1271.1	8694.6	92.3	30.7
396	anansedodowaa	*Cola millenii*	Sterc	697.4	14071.4	2857.2	844.2	15555.2	29.2	376.4	4971.8	3117.9	49.2	1614.3	6012.6	53.2	24.9
397	odwono	*Baphia nitida*	Papi	774.1	13552.7	2053.6	369.8	7645.5	11.7	195.8	2078.5	1093.3	22.6	1340.3	2849.2	45.4	26.9
399	penkwa	*Entandrophragma cylindricum*	Meli	749.6	7272.4	4369.8	655.1	12953.3	9.8	253.0	1938.6	651.0	19.8	622.6	10852.5	72.0	7.1
418	sonkyi	*Allanblackia parviflora*	Gutt	563.4	6825.6	3446.5	431.3	7921.4	25.6	203.9	3145.3	60.3	27.3	1133.1	4368.5	52.8	39.3
430	funtum bre	*Funtumia africana*	Sterc	420.3	9678.6	2055.3	459.8	7368.4	4.4	1148.9	5176.4	964.2	42.8	910.5	3357.8	42.9	3.6
431	anansedodowaa	*Cola millenii*	Sterc	702.2	16190.5	1735.9	392.8	9432.9	6.8	194.6	3250.2	865.2	35.9	1121.5	2002.8	53.3	23.4
436	obaa	*Xylopia quintasii*	Anno	679.9	15763.2	2194.5	270.5	4665.4	11.8	214.4	1628.1	740.5	16.2	1295.6	2281.5	28.0	28.1
439	tanuro	*Trichilia monadelpha*	Meli	733.7	4615.1	2422.6	435.8	8109.4	8.6	244.9	3638.4	4.0	42.3	1627.5	6615.0	67.1	17.0

Inventory and total element concentrations (mg kg^{-1}) of barks of tree species in Tinte-Bepo Reserved Primary Forest.

Tree No	Local Name	Scientific Name	Family Name	Element (mg kg^{-1}) Na	K	S	Al	Ca	Cu	Fe	Mg	Mn	Mo	P	Si	Sr	Zn
84	esakokoo	*Celtis zenkeri*	Ulma	24.6	1791.7	55565.4	11799.4	15563.6	585.4	2941.4	5960.2	2951.3	64.1	2999.8	782.5	643.2	582.9
85	dwedwedwedwe	*Dialium dinklagei*	Caes	133.3	3618.8	2463.0	17022.6	13495.2	18.5	33.3	780.3	36.8	103.2	181.3	686.4	102.0	29.7
88	ntwesono	*Aulacocalyx jasminiflora*	Rubi	331.3	2392.9	1104.8	1060.3	22075.3	18.6	25.0	1948.3	172.3	81.3	71.2	586.8	292.4	8.0
89	odwono	*Baphia nitida*	Papi	230.0	3474.6	2196.4	814.3	11369.2	20.0	73.9	654.6	283.9	73.8	191.8	630.7	75.3	27.9
90	anansedodowaa	*Cola millenii*	Sterc	19.2	3690.4	55565.8	11992.4	38923.7	585.7	2929.2	13808.5	2971.3	219.1	3014.5	744.3	661.5	584.2
91	nyankomanini	*Myrianthus libericus*	Mora	2.5	7812.5	96.8	11703.8	8019.6	586.8	2938.2	6604.2	2906.3	20.8	3015.8	0.0	614.6	582.8
92	fotie/hotrohotro	*Anthocleista nobilis*	Loga	321.3	13891.7	1856.7	1372.7	40787.7	13.1	36.9	1083.3	0.0	67.8	71.7	667.4	145.3	6.3
94	funtum	*Funtumia elastica*	Apoc	355.5	2034.0	66682.5	14192.5	27462.1	702.5	3478.7	7222.2	3506.4	76.0	3592.8	879.8	821.7	699.1
95	esakokoo	*Celtis zenkeri*	Ulma	99.3	8107.1	47632.9	10007.4	7295.3	501.4	2502.7	5216.6	2574.4	50.3	2594.1	600.9	512.5	504.7
111	odwono	*Baphia nitida*	Papi	335.0	4424.5	311.2	669.5	13647.3	22.9	84.8	544.7	35.2	81.0	256.2	641.4	153.9	3.4
112	kaakaadikro	*Trichilia prieuriana*	Meli	175.0	7237.5	6088.4	1455.7	39548.7	23.1	81.3	3385.3	220.3	93.7	315.3	576.8	158.3	15.4
113	dubinkokoo	*Khaya ivorensis*	Meli	203.6	2697.5	47631.1	10240.1	22921.5	503.5	2525.3	5529.5	2483.3	58.4	2599.4	696.3	575.5	502.3
114	dubinbre	*Lovoa trichilloides*	Meli	220.8	3099.6	3285.0	1238.4	31405.4	12.5	69.9	1356.2	0.0	60.9	286.0	633.8	147.5	24.8
115	motokrodua	*Monodora tamifolia*	Anno	382.5	3481.7	2409.8	1061.8	22861.5	21.5	18.3	767.1	61.9	76.7	99.7	586.2	94.1	9.4
122	otwese	*Memecylon lateriflorum*	Melas	6.4	2700.7	47628.6	10134.4	15275.5	502.2	2518.1	5146.4	2591.9	58.5	2587.5	630.2	511.6	501.9
123	tanuro	*Trichilia monadelpha*	Meli	19.2	14245.8	55568.3	11698.7	10451.8	583.8	2907.8	6287.6	2894.0	64.0	3012.2	678.3	613.8	582.2
124	pobe	*Massularia acuminata*	Rubi	219.6	2450.4	55569.2	11873.8	25897.8	586.0	2900.8	5952.9	2922.0	63.5	3009.4	742.6	683.0	582.9
125	pobe	*Massularia acuminata*	Rubi	119.2	2952.5	97.0	11894.1	26305.6	587.6	2899.5	5908.0	2895.4	10.9	2987.6	0.0	685.4	588.7
126	danta	*Nesogordonia papaverifera*	Sterc	205.0	5285.7	2366.3	667.4	11054.4	11.5	59.0	689.1	128.4	53.9	124.0	578.8	75.5	12.0
127	otwese	*Memecylon lateriflorum*	Melas	473.6	8346.4	1679.2	541.0	10367.4	229.4	196.8	489.6	274.9	49.9	398.7	526.9	65.3	21.0
128	kaakaadikro	*Trichilia prieuriana*	Meli	509.5	1781.5	1563.8	1532.0	37605.6	22.5	134.5	353.5	167.2	82.0	28.3	759.1	186.5	9.4
129	afena	*Strombosia glaucescens*	Olac	426.7	2831.7	954.0	631.8	6474.2	18.9	27.7	1374.2	0.0	81.0	126.3	681.4	72.3	18.4
130	fema	*Microdesmis puberula*	Pand	39.3	2842.9	82.4	10310.1	25819.6	502.9	2545.6	5144.5	2586.1	0.4	2582.7	0.0	522.3	502.1
131	kyereye	*Pterygota marcrocarpa*	Sterc	11.8	2694.6	83.2	10125.3	17311.6	502.4	2489.6	6490.3	2704.3	40.5	2641.8	0.0	539.1	506.1
133	esakokoo	*Celtis zenkeri*	Ulma	493.9	3277.1	3236.7	1130.0	24141.8	12.0	113.6	1134.3	226.4	57.8	130.3	603.8	119.0	10.4
134	pampenama	*Corynanthe pachyceras*	Rubi	272.9	2447.1	822.9	1024.5	29279.9	17.9	156.5	358.1	36.7	63.8	297.5	480.3	365.0	19.6
135	odwono	*Baphia nitida*	Papi	39.2	5516.7	55565.0	11909.9	23978.0	585.2	2953.6	6356.9	2919.5	71.2	2992.5	779.0	621.5	588.4
136	odwono	*Baphia nitida*	Papi	77.5	3460.5	66680.0	14099.2	17828.9	703.4	3521.5	10122.2	3539.0	130.9	3815.8	906.2	760.1	700.4
138	duabankye	*Dialium aubrevillei*	Caes	348.3	3627.5	359.9	621.4	6545.9	17.6	55.5	488.6	192.6	72.7	194.0	631.5	54.0	27.9
139	edinam	*Entandrophragma angolense*	Meli	273.0	5060.0	1504.4	1084.9	19421.9	27.8	28.9	1980.9	0.0	103.2	193.2	705.3	94.5	17.9

144	fema	*Microdesmis puberula*	Pand	396.7	5362.5	2289.2	1179.4	9370.8	13.2	605.0	1420.7	241.3	67.8	219.0	620.2	79.6	25.4
145	odwono	*Baphia nitida*	Papi	316.7	5175.0	3298.6	1130.1	24765.2	21.3	57.5	719.7	370.5	70.6	85.5	694.7	116.3	35.9
146	afena	*Strombosia glaucescens*	Olac	315.8	4333.3	2526.0	1522.1	43324.4	14.0	134.3	4294.5	0.0	89.7	151.9	691.2	190.8	11.5
148	pampenama	*Corynanthe pachyceras*	Rubi	183.0	4262.0	1743.8	1191.7	23704.4	21.8	53.6	2915.5	0.0	98.0	169.4	711.1	114.6	13.7
149	bese	*Cola nitida*	Sterc	535.0	2212.0	66818.5	14106.4	19746.6	702.0	3486.6	7418.8	3470.9	72.8	3564.1	846.6	756.0	699.1
150	kyereye	*Pterygota marcrocarpa*	Sterc	339.6	1018.3	1006.5	1125.8	24241.5	21.4	255.1	10434.0	250.6	143.3	279.0	762.2	143.6	10.7
151	kaakaadikro	*Trichilia prieuriana*	Meli	460.0	2274.5	2069.1	926.7	23216.2	24.9	81.6	2868.5	30.6	99.2	257.2	619.4	230.0	40.5
152	odwono	*Baphia nitida*	Papi	466.7	2627.9	1086.5	1192.9	27821.5	23.4	18.3	955.6	0.0	78.3	72.1	704.6	256.7	9.3
153	dubinbre	*Lovoa trichilloides*	Meli	332.5	6487.5	5543.1	451.4	9467.0	11.5	91.3	5629.9	111.2	89.6	155.5	498.1	67.1	7.8
154	okure	*Trilepisium madascariense*	Mora	101.5	4806.0	116.4	14235.2	28451.5	704.5	3487.5	7116.6	3476.1	4.2	3590.5	0.0	842.8	706.2
155	odwono	*Baphia nitida*	Papi	484.6	3455.8	918.9	1093.8	25690.7	17.6	6.3	293.0	0.0	61.3	62.0	629.8	347.8	16.5
156	duade	*Craterispermum caudatum*	Rubi	234.5	754.5	1237.6	1564.2	40152.9	12.3	22.6	4318.2	178.4	94.9	24.6	740.1	343.5	8.5
157	dubinbre	*Lovoa trichilloides*	Meli	377.9	2232.5	1397.7	1090.5	32137.8	14.3	98.3	864.4	145.1	61.7	251.2	593.9	395.9	3.8
158	dubinbre	*Lovoa trichilloides*	Meli	53.6	1560.4	83.2	10287.2	11946.5	503.4	2673.7	5860.9	2513.9	27.3	2572.3	0.0	530.0	511.3
159	dwendweraa	*Lecaniodiscus cupanioides*	Sapin	420.4	2354.2	1972.4	1282.8	31137.7	14.5	36.7	2425.2	38.3	78.7	61.4	674.6	193.0	23.1
161	anansedodowaa	*Cola millenii*	Sterc	961.5	7880.0	2345.6	684.3	5661.6	22.8	23.4	1551.3	320.4	126.2	100.8	716.7	49.7	58.2
162	duasika	*Enantia polycarpa*	Anno	260.0	2557.5	775.4	780.6	20575.6	17.9	93.8	218.2	29.9	63.8	289.4	563.2	238.8	17.5
163	sopi	*Daniellia thurifera*	Caes	915.4	3227.5	894.2	9706.1	11551.5	19.8	25.8	1397.0	540.0	94.0	75.9	622.9	125.4	33.3
165	duawisa	*Isolona campanulata*	Anno	1746.0	472.5	1046.5	9184.5	13511.1	22.9	34.7	1379.1	468.1	102.1	42.4	752.6	126.5	11.6
166	pampenama	*Corynanthe pachyceras*	Rubi	498.3	2197.9	5004.3	1078.5	27454.8	7.6	24.7	656.5	130.1	44.3	32.3	664.3	81.2	7.6
168	pampenama	*Corynanthe pachyceras*	Rubi	359.6	2999.6	55569.2	11898.5	27218.2	586.7	2958.4	6464.6	2928.7	80.2	2998.0	734.3	635.2	586.3
170	sonkyi	*Allanblackia parviflora*	Gutt	62.9	1892.1	83.2	10244.0	27224.5	502.6	2492.2	5670.6	2562.0	20.4	2561.3	0.0	555.2	503.4
171	esakokoo	*Celtis zenkeri*	Ulma	541.0	7520.0	2007.1	622.1	11678.5	21.4	320.1	1361.4	297.4	87.5	308.7	620.4	71.7	24.7
174	bese	*Cola nitida*	Sterc	581.5	1720.5	2606.3	1179.9	25433.2	25.5	20.0	1704.1	201.8	86.0	96.4	693.4	152.8	11.5
175	bese	*Cola nitida*	Sterc	365.5	3480.0	1827.7	811.9	19483.7	23.5	111.9	2865.4	118.8	93.1	282.5	625.0	136.5	16.9
176	motokrodua	*Monodora tamifolia*	Anno	151.7	8533.3	97.0	11765.1	8228.5	590.0	2959.5	7379.8	3024.2	47.7	3052.6	0.0	602.5	591.7
177	pampenama	*Corynanthe pachyceras*	Rubi	318.5	11285.0	1458.4	963.7	25464.2	17.0	745.7	1035.9	34.0	68.7	303.3	614.1	141.0	1.7
178	duade	*Craterispermum caudatum*	Rubi	3.5	1818.5	116.4	14098.9	15918.3	703.0	3499.3	7114.0	3497.3	0.0	3582.6	0.0	747.2	704.7
179	duade	*Craterispermum caudatum*	Rubi	768.0	715.0	1957.9	17230.2	24121.1	27.1	35.1	1666.6	747.7	128.1	149.3	802.1	183.6	23.8
180	fema	*Microdesmis puberula*	Pand	149.0	2273.0	1147.9	974.0	16575.5	25.5	22.9	529.7	0.0	85.6	128.7	679.3	184.0	45.7
181	bese	*Cola nitida*	Sterc	554.5	3420.0	66682.0	14182.8	24694.6	703.8	3480.4	7067.1	3475.3	78.2	3585.5	861.2	803.0	704.9
182	odwono	*Baphia nitida*	Papi	188.3	9720.8	2193.3	1356.5	19168.7	9.1	414.6	5287.8	47.2	85.0	91.8	672.2	192.0	15.0
183	odwono	*Baphia nitida*	Papi	385.4	3197.9	1253.8	1073.5	21888.3	16.3	70.5	1175.2	130.1	74.4	197.0	683.4	228.4	8.3
186	hwenteaa	*Xylopia aethiopica*	Anno	338.2	3020.4	3596.8	1119.6	43042.7	14.8	83.6	637.0	398.4	46.1	259.6	435.8	138.2	19.2

187	odwono	*Baphia nitida*	Papi	31.7	16720.8	55567.9	11970.1	33794.6	584.9	2929.1	6157.3	2894.2	65.9	3012.4	718.7	636.5	582.9
188	pampenama	*Corynanthe pachyceras*	Rubi	3.8	1775.0	96.8	11883.1	14805.9	586.6	2942.4	6468.6	2912.5	15.5	2996.3	0.0	657.2	592.2
189	duawisa	*Isolona campanulata*	Anno	429.6	4242.9	2377.8	1116.5	28191.3	12.8	102.6	1766.3	270.2	61.9	101.1	556.3	183.7	15.1
190	fotie/hotrohotro	*Anthocleista nobilis*	Loga	824.2	604.6	822.0	11262.5	13794.5	21.6	119.7	1556.0	422.2	98.0	276.3	635.7	138.0	19.1
193	esakokoo	*Celtis zenkeri*	Ulma	7141.7	10.4	2649.2	2186.5	30837.0	111.2	1522.3	1301.6	226.2	120.4	1216.8	1058.9	293.1	1159.9
194	duade	*Craterispermum caudatum*	Rubi	266.5	3006.0	116.5	14191.9	23610.5	705.1	4983.6	7101.1	3475.9	9.1	3577.2	0.0	791.0	705.6
195	pampenama	*Corynanthe pachyceras*	Rubi	352.0	2647.5	66684.0	14086.2	16324.8	703.4	3336.0	8091.7	3501.8	97.9	3586.0	883.0	735.3	702.0
197	pampenama	*Corynanthe pachyceras*	Rubi	565.8	2036.3	1048.4	1219.3	28816.9	19.3	26.8	1325.7	100.7	75.2	86.4	595.4	420.5	8.3
198	nwama	*Ricinodendron heudelotii*	Euph	509.5	748.5	274.6	244.5	0.0	15.0	52.4	0.0	17.8	63.0	81.2	492.7	6.8	0.0
199	ohaa	*Sterculia oblonga*	Sterc	111.8	3260.0	5158.8	1235.5	33835.7	13.4	145.1	502.1	213.1	48.9	182.4	580.6	127.4	12.0
200	esakokoo	*Celtis zenkeri*	Ulma	311.3	5325.0	650.0	665.3	8802.3	17.5	14.6	3175.1	125.1	86.4	55.2	588.9	83.5	8.1
201	duade	*Craterispermum caudatum*	Rubi	304.0	4951.0	1074.7	1106.2	17524.6	24.5	35.3	309.2	0.0	81.9	124.8	686.8	262.0	22.6
203	fotie/hotrohotro	*Anthocleista nobilis*	Loga	460.0	6125.0	2665.0	1234.3	28858.2	19.6	42.2	5263.5	83.4	105.1	104.4	621.4	211.0	19.0
204	funtum	*Funtumia elastica*	Apoc	342.1	2525.7	3348.0	1315.8	36365.9	20.0	102.1	1628.4	0.0	72.2	178.6	651.9	277.8	10.2
205	odwono	*Baphia nitida*	Papi	585.8	2275.4	4421.9	1310.6	32520.0	6.0	67.8	354.1	172.3	43.7	21.0	681.2	100.2	8.0
206	duade	*Craterispermum caudatum*	Rubi	40.4	5589.3	83.1	10314.8	26616.3	503.4	2550.8	5649.8	2526.1	19.6	2572.3	0.0	572.1	505.4
207	esakokoo	*Celtis zenkeri*	Ulma	417.5	4915.5	4047.0	1412.9	33319.0	22.9	20.1	1963.9	0.0	95.4	269.3	692.8	259.0	19.2
209	pampenama	*Corynanthe pachyceras*	Rubi	368.8	1223.3	1874.3	1180.4	18829.5	19.1	223.3	1283.3	49.9	76.3	164.3	656.0	144.6	10.0
212	bese	*Cola nitida*	Sterc	371.0	3704.0	2014.5	1333.8	30449.2	21.2	37.5	541.0	106.6	84.9	93.4	890.0	300.7	10.4
213	ntwesono	*Aulacocalyx jasminiflora*	Rubi	150.7	2894.6	83.1	10128.6	21353.6	504.0	2533.3	5180.1	2595.9	11.2	2601.3	0.0	520.2	501.6
214	pobe	*Massularia acuminata*	Rubi	637.5	3549.0	724.4	678.7	15270.1	23.1	199.8	291.1	30.9	72.0	320.5	103.6	184.0	15.7
215	fema	*Microdesmis puberula*	Pand	610.0	3025.5	2370.1	1915.0	39071.0	22.7	320.3	837.4	68.2	87.8	159.4	922.7	442.3	12.5
216	motokrodua	*Monodora tamifolia*	Anno	446.5	3079.5	66683.0	14090.6	16385.0	704.2	3489.0	7012.4	3472.4	80.0	3588.9	853.0	766.4	705.5
217	pampenama	*Corynanthe pachyceras*	Rubi	826.5	4200.0	1281.8	586.4	8976.5	27.4	1184.3	1516.4	30.1	90.4	531.2	688.1	85.2	22.6
219	bese	*Cola nitida*	Sterc	350.5	5455.0	331.0	164.4	0.0	3.8	44.5	0.0	16.2	41.0	16.9	470.8	6.2	0.0
220	otwese	*Memecylon lateriflorum*	Melas	276.4	4275.0	47630.0	10334.8	24853.0	501.2	2648.3	7560.8	2542.5	90.9	2576.1	659.5	549.4	499.7
222	ntwesono	*Aulacocalyx jasminiflora*	Rubi	443.3	2912.9	2544.6	1636.4	45311.5	22.0	119.3	1901.3	72.6	84.5	326.6	733.6	197.6	20.1
223	odwonkobire	*Baphia pubescens*	Papi	20.0	695.7	83.3	10303.4	38755.6	502.8	2487.7	5141.5	2504.1	7.1	2552.3	0.0	634.1	500.3
224	ntwesono	*Aulacocalyx jasminiflora*	Rubi	621.5	24060.0	932.7	929.4	13139.6	19.1	91.3	1278.2	10.4	79.4	116.9	829.7	82.0	9.2
225	duabankye	*Dialium aubrevillei*	Caes	373.3	3275.0	1086.3	1166.8	24562.3	21.5	81.9	464.0	0.0	75.0	196.8	731.1	296.1	25.7
226	esakokoo	*Celtis zenkeri*	Ulma	101.3	2237.1	760.9	626.3	5341.1	20.5	31.6	1506.8	31.6	81.2	34.5	586.4	73.0	24.9
227	fema	*Microdesmis puberula*	Pand	464.0	5120.0	622.0	531.9	2325.1	9.7	0.0	75.6	0.0	60.6	0.0	677.5	47.8	3.8
228	pampenama	*Corynanthe pachyceras*	Rubi	271.5	1877.5	6063.7	968.5	25378.2	20.8	100.1	369.4	282.8	77.5	231.9	584.7	70.1	3.9
230	esakokoo	*Celtis zenkeri*	Ulma	316.5	6795.0	1785.7	1310.4	27495.1	16.0	104.6	558.3	102.4	73.6	0.0	979.9	326.0	9.3

231	pampenama	*Corynanthe pachyceras*	Rubi	310.4	4408.3	55567.5	11812.8	14866.5	588.1	3398.8	5976.3	4159.3	73.0	3069.1	782.5	662.6	588.1
232	edinam	*Entandrophragma angolense*	Meli	148.5	2771.0	66683.0	14116.0	19601.5	702.8	3498.9	8804.2	3489.7	107.1	3584.0	836.5	761.2	706.4
233	pampenama	*Corynanthe pachyceras*	Rubi	329.2	4179.2	8028.2	16789.3	22116.7	581.8	3092.1	5933.3	2947.9	58.2	3008.1	801.8	617.8	586.8
235	anansedodowaa	*Cola millenii*	Sterc	89.5	7375.0	66678.5	14007.0	8990.5	703.5	3538.9	7058.5	3539.3	73.3	3551.3	1026.2	728.4	864.0
236	tanuro	*Trichilia monadelpha*	Meli	520.0	2690.5	1722.2	1159.1	32797.0	21.9	98.8	2414.0	78.2	89.9	337.2	606.6	430.5	89.4
237	esakokoo	*Celtis zenkeri*	Ulma	394.0	1977.0	1063.3	1176.8	23279.2	25.9	43.4	330.6	0.0	89.5	110.9	797.7	279.6	26.2
238	hyedua	*Daniella ogea*	Caes	883.5	2652.5	1068.5	1076.4	19059.5	19.4	137.2	1273.1	0.0	76.2	68.4	836.6	163.6	9.4
239	pampenama	*Corynanthe pachyceras*	Rubi	152.1	5232.1	47630.7	16546.6	17773.1	500.9	2490.5	5266.6	2495.9	77.5	2595.4	663.2	542.9	511.4
240	potrodom	*Erythrophleun ivorense*	Caes	52.1	5000.0	83.1	17770.4	14819.6	503.3	2484.8	5111.6	2508.9	56.0	2606.0	0.0	531.2	500.3
244	pobe	*Massularia acuminata*	Rubi	1212.5	1173.0	1541.5	13149.8	22081.5	19.4	276.8	3085.2	609.6	117.3	266.9	611.9	180.8	37.9
245	fema	*Microdesmis puberula*	Pand	241.0	9650.0	3005.6	948.6	15576.8	22.4	38.8	513.9	88.7	88.3	167.7	792.2	96.9	38.4
246	esakokoo	*Celtis zenkeri*	Ulma	190.0	6345.0	606.9	7208.9	12324.1	24.1	10.3	46.8	0.0	97.8	79.9	688.2	84.7	36.2
247	pampenama	*Corynanthe pachyceras*	Rubi	395.4	4121.4	83.3	10428.5	47083.8	503.5	2506.9	5112.7	2589.8	8.9	2573.4	0.0	554.6	526.6
248	bese	*Cola nitida*	Sterc	134.2	5375.0	3202.0	831.3	14032.2	18.2	25.2	4087.4	0.0	98.2	126.7	673.8	127.3	10.6
249	apotrowa	*Maesobotrya barteri*	Euph	353.5	4287.0	3802.9	874.7	19974.8	44.4	274.2	2506.2	28.0	99.8	595.6	607.3	175.0	5.6
251	motokrodua	*Monodora tamifolia*	Anno	306.0	3504.0	1501.1	1219.1	24241.4	22.1	47.5	1362.4	161.1	92.2	135.1	803.4	298.4	10.7
252	funtum	*Funtumia elastica*	Apoc	283.5	5415.0	742.8	656.0	7725.4	2.5	47.7	193.4	0.0	44.9	0.0	802.3	49.6	44.4
253	pampenama	*Corynanthe pachyceras*	Rubi	438.3	3957.1	3135.5	1108.3	32008.5	16.1	118.7	1535.6	29.0	69.9	555.1	494.9	276.8	17.6
256	totro	*Anthonotha macrophylla*	Caes	741.5	7655.0	2434.5	1446.9	33648.5	24.7	70.7	811.6	0.0	89.2	361.7	799.9	133.3	44.9
257	dwedwedwedwe	*Dialium dinklagei*	Caes	397.1	4775.0	1133.0	814.4	15649.9	14.6	74.9	517.4	38.4	53.7	416.5	611.9	175.1	8.0
259	dubinkokoo	*Khaya ivorensis*	Meli	146.1	1855.4	47629.6	10229.8	25321.0	501.1	2510.9	5767.8	2541.0	54.8	2617.8	693.1	600.8	504.5
260	duade	*Craterispermum caudatum*	Rubi	1.3	3093.3	96.6	12073.5	26838.3	585.2	3126.4	9164.2	2936.1	78.8	2989.3	0.0	627.1	583.2
261	odwono	*Baphia nitida*	Papi	9.5	4409.0	66678.0	14424.6	30090.4	703.1	3575.8	8411.2	3575.0	105.0	3613.3	869.9	731.4	757.5
262	pampenama	*Corynanthe pachyceras*	Rubi	219.2	6358.3	55567.5	11900.3	22693.0	587.8	2958.5	9012.3	2952.8	129.8	3038.0	805.9	634.7	583.7
263	afena	*Strombosia glaucescens*	Olac	557.9	4001.7	800.6	924.0	24881.8	18.4	90.7	261.2	24.5	62.0	231.7	500.3	304.4	11.3
265	nwama	*Ricinodendron heudelotii*	Euph	263.0	3651.5	2351.7	989.4	15991.4	22.9	38.3	688.7	40.6	88.6	124.4	801.4	75.5	12.7
266	denya	*Cylicodiscus gadunensis*	Mimo	441.5	4277.5	66684.0	14225.5	29663.3	703.7	3496.3	7681.1	3496.8	84.9	3626.4	869.7	813.6	718.9
268	ntwesono	*Aulacocalyx jasminiflora*	Rubi	1008.5	7425.0	1225.1	1304.7	18396.6	14.4	284.0	1802.4	185.4	75.1	115.9	832.9	116.0	83.2
269	bonsamdua	*Disthemonanthus bentamianus*	Caes	310.8	2864.2	2487.9	1209.1	28782.0	15.7	69.7	1276.2	0.0	68.7	239.5	670.8	137.0	35.6
270	akye	*Blighia sapida*	Sapin	466.5	1578.5	116.7	14151.6	20634.7	704.2	3482.8	7745.3	3470.0	30.2	3580.0	0.0	742.3	701.8
271	kaakaadikro	*Trichilia prieuriana*	Meli	259.6	3570.4	3576.9	969.3	26136.7	21.9	161.5	1878.8	25.3	79.0	472.5	511.8	68.0	32.1
272	ohaa	*Sterculia oblonga*	Sterc	552.5	7729.2	2216.8	722.3	10562.6	20.3	24.6	607.2	261.9	70.8	268.4	589.3	65.5	29.8
273	pobe	*Massularia acuminata*	Rubi	62.0	3380.5	116.2	14295.1	21957.8	705.2	3589.2	7946.7	3496.0	28.7	3584.4	0.0	731.1	705.9
274	anansedodowaa	*Cola millenii*	Sterc	262.1	16362.5	1849.5	1191.3	28085.5	14.1	67.7	1433.7	0.0	69.2	91.8	677.7	148.5	8.6

275	pobe	*Massularia acuminata*	Rubi	192.5	3044.2	55575.8	11888.8	27766.3	587.1	3257.4	6262.3	2904.8	68.6	3045.8	715.2	704.1	586.4
276	anansedodowaa	*Cola millenii*	Sterc	349.6	8014.3	1405.5	1180.2	36839.9	10.3	594.1	1556.4	71.4	52.0	111.4	581.4	272.3	46.1
277	kaakaadikro	*Trichilia prieuriana*	Meli	215.8	4233.3	55569.2	11872.1	25536.9	586.6	3124.2	6080.0	2925.9	66.3	3021.9	725.8	664.4	586.4
278	dwendweraa	*Lecaniodiscus cupanioides*	Sapo	371.8	1294.6	4797.2	10165.1	19042.9	499.7	2529.5	5601.7	2490.4	44.3	2605.9	629.4	521.4	500.5
279	funtum	*Funtumia elastica*	Apoc	31.7	1043.8	97.3	11817.5	18859.1	587.1	2899.0	5877.8	2908.9	6.1	2987.5	0.0	624.8	589.4
280	otwese	*Memecylon lateriflorum*	Melas	172.0	4086.5	0.0	1213.1	28294.6	15.1	64.8	3527.2	0.0	89.1	50.8	774.4	145.2	8.0
293	kaakaadikro	*Trichilia prieuriana*	Meli	229.3	12621.4	1805.8	1052.7	14798.9	6.9	38.8	488.5	0.0	42.3	0.0	626.9	144.5	3.3
294	tanuronini	*Trichilia tessmanii*	Meli	192.9	1542.9	97.0	11944.5	24455.2	587.3	2953.0	6249.0	2907.6	15.3	3000.8	0.0	673.0	589.9
295	tanuronini	*Trichilia tessmanii*	Meli	389.6	4466.7	1350.5	1976.3	30380.0	22.8	15.9	904.4	477.9	77.2	190.8	651.1	289.9	18.6
296	odwono	*Baphia nitida*	Papi	358.9	2638.6	5732.6	1157.5	24185.1	14.8	149.4	466.0	112.7	56.1	116.3	666.9	61.5	12.3
297	bese	*Cola nitida*	Sterc	504.6	4862.5	3463.0	16674.0	27699.1	15.2	626.0	1213.4	35.1	93.0	211.3	631.6	137.0	25.9
298	nakwa	*Holoptelea grandis*	Ulma	145.0	474.3	83.4	10445.5	40826.0	503.9	2608.8	5521.4	2498.0	17.6	2557.8	0.0	611.2	502.5
300	pobe	*Massularia acuminata*	Rubi	331.0	2267.0	1054.7	1529.7	20620.4	22.3	454.0	11358.1	45.3	161.3	144.4	808.1	132.4	12.1
301	funtum	*Funtumia elastica*	Apoc	316.0	5295.0	2301.3	1032.0	27644.2	21.8	89.2	634.8	142.7	84.2	358.9	572.4	192.5	13.0
304	funtum	*Funtumia elastica*	Apoc	146.3	1287.1	55568.3	12204.5	64767.3	585.4	2953.1	7184.2	2929.9	82.8	2986.5	797.7	748.0	583.1
308	fotie/hotrohotro	*Anthocleista nobilis*	Loga	549.0	3753.0	2136.6	957.3	10896.0	10.7	206.0	1367.2	21.6	66.7	25.8	799.7	83.6	19.1
387	dahoma	*Piptadeniastrum africanum*	Mimo	421.5	4415.5	1350.4	1283.4	36802.8	16.0	104.1	739.3	63.7	74.5	282.2	625.2	387.1	2.8
388	wawa	*Triplochiton scleroxylon*	Sterc	324.2	9450.0	1377.1	1478.9	46346.5	19.9	74.9	772.5	262.1	68.5	345.5	482.7	460.0	23.6
389	akyebire	*Blighia welwitschii*	Sapin	589.0	15635.0	1789.4	1258.2	25685.2	21.4	110.9	1444.7	0.0	92.2	147.7	850.7	166.2	9.9
390	funtum	*Funtumia elastica*	Apoc	234.2	836.7	55568.8	11746.0	8022.7	586.4	2957.2	7431.1	2996.1	95.0	3009.4	793.6	623.9	584.1
392	pobe	*Massularia acuminata*	Rubi	333.8	14012.5	4485.3	889.1	19104.0	8.1	49.8	1202.0	0.0	48.9	173.4	601.2	412.2	13.2
393	fema	*Microdesmis puberula*	Pand	655.5	4667.5	7844.3	1025.1	28533.0	18.8	245.2	3278.0	42.1	92.1	212.8	600.2	318.4	16.6
394	dwedwedwedwe	*Dialium dinklagei*	Caes	225.4	1179.2	5181.8	1170.3	25959.8	22.5	43.4	688.8	186.1	73.0	136.0	601.0	89.5	14.3
395	sonkyi	*Allanblackia parviflora*	Gutt	803.0	3153.5	972.1	961.9	13664.8	25.4	70.8	1755.6	130.4	97.7	77.4	754.7	92.3	15.4
396	anansedodowaa	*Cola millenii*	Sterc	424.6	3289.2	913.9	943.3	18729.7	15.0	100.8	2090.2	0.0	74.5	35.6	661.1	105.3	10.0
397	odwono	*Baphia nitida*	Papi	118.8	2222.9	5684.3	1093.9	23426.5	12.6	66.1	514.8	195.3	58.3	135.0	698.2	84.5	10.7
399	penkwa	*Entandrophragma cylindricum*	Meli	354.5	8110.0	167.8	418.5	155.6	13.8	52.6	0.0	24.4	59.3	81.3	492.3	8.8	0.0
418	sonkyi	*Allanblackia parviflora*	Gutt	1018.5	12860.0	2482.8	1204.6	23980.8	28.5	29.8	2403.7	243.6	103.8	165.0	716.1	123.8	11.5
430	funtum bre	*Funtumia africana*	Sterc	408.8	2586.7	1609.6	632.8	7248.1	19.4	139.3	855.2	178.8	76.3	96.1	652.5	59.2	19.4
431	anansedodowaa	*Cola millenii*	Sterc	530.0	5050.0	2441.5	955.1	10886.0	29.8	118.0	1741.9	119.3	100.4	291.7	792.7	74.7	22.4
436	obaa	*Xylopia quintasii*	Anno	755.5	5220.0	1178.4	1229.9	25923.0	22.9	14.6	3928.5	0.0	110.8	122.8	739.5	230.8	10.0
439	tanuro	*Trichilia monadelpha*	Meli	453.3	1651.3	1860.3	1116.8	25324.0	14.6	62.1	1581.3	0.0	71.7	97.0	686.5	243.3	10.3

Appendix C: Inventory and total element concentrations (mg kg^{-1}) of leaves of tree species in Akyaakrom Secondary Forest (AS)

Plot No	Tree No	Local Name	Scientific Name	Family Name	Element (mg kg^{-1})													
					Na	K	S	Al	Ca	Cu	Fe	Mg	Mn	Mo	P	Si	Sr	Zn
3	1	Sinuro	*Alstonia boonei*	Apoc	468.2	22955.8	1796.4	411.9	5824.1	4.1	274.2	2543.6	42.0	24.2	1247.1	4643.7	32.3	15.3
3	2	Pepea	*Magaritaria discoidea*	Euph	504.5	16629.4	5767.3	601.3	15192.5	1.3	299.5	3288.9	217.0	30.4	1262.3	4467.6	119.3	21.6
3	3	Sofo	*Sterculia tragacantha*	Sterc	606.5	16252.6	2041.6	805.0	17133.1	2.3	262.8	4887.1	268.3	48.0	1058.2	5144.2	135.2	62.7
3	5	Pepea	*Magaritaria discoidea*	Euph	857.1	14672.6	3506.9	471.8	11769.8	0.1	258.9	2673.0	156.3	23.6	816.9	5178.5	85.5	19.2
3	7	Akyebire	*Blighia unijugata*	Sapin	575.4	8813.5	11270.0	369.1	4165.2	0.0	175.7	1038.2	35.8	12.8	328.4	4538.8	27.0	3.1
3	8	Tanuro	*Trichilia monadelpha*	Meli	521.9	8097.0	3583.8	2244.6	46803.5	2.1	721.3	2649.6	138.1	25.3	645.5	14983.6	310.0	23.2
3	9	Okro	*Albizia zygia*	Mimo	460.7	9868.6	2189.6	281.7	5489.9	0.0	179.8	2265.7	137.9	19.5	872.8	4794.2	16.9	0.9
3	10	Pepea	*Magaritaria discoidea*	Euph	532.0	14693.8	5423.6	515.0	12956.3	0.0	181.0	3065.8	241.3	25.2	1002.6	4918.7	96.7	17.5
3	11	Dubrafo	*Mareya micrantha*	Euph	711.6	10063.7	1746.7	1177.8	20773.3	0.0	372.8	3083.3	52.6	29.9	399.0	27614.6	185.0	0.0
3	12	Domini	*Ficus capensis*	Mora	508.1	22051.4	1544.0	639.5	18503.3	0.3	157.3	4096.6	59.5	33.4	813.3	5235.0	138.2	11.9
3	13	Tanuro	*Trichilia monadelpha*	Meli	1014.5	16976.1	1674.0	870.1	8117.9	3.0	464.2	1804.5	49.2	18.9	767.9	4725.8	67.0	8.0
3	14	Wawa	*Triplochiton scleroxylon*	Sterc	836.3	25488.1	2852.6	290.4	5113.6	5.3	218.5	2589.6	38.6	138.3	1293.8	6813.7	23.5	8.5
3	15	Okro	*Albizia zygia*	Mimo	505.4	11001.8	2463.5	248.1	5575.7	0.8	195.8	2388.4	187.7	21.5	1006.7	461.6	12.1	5.3
3	16	Funtum	*Funtumia elastica*	Apoc	571.4	9411.1	1501.3	872.6	13329.3	0.0	352.1	3383.1	172.6	35.3	465.6	5012.5	72.7	4.1
3	17	Doma	*Ficus leprieuri*	Mora	467.3	23917.8	2447.9	794.0	20962.0	2.9	218.8	5052.9	59.9	45.9	1218.5	8710.5	150.2	19.4
3	18	Nwama	*Ricinodendron heudelotii*	Euph	728.0	2653.4	1462.8	953.3	22214.0	6.0	227.3	2001.3	43.3	23.9	311.0	17608.1	163.8	0.0
3	20	Sinuro	*Alstonia boonei*	Apoc	501.6	15941.0	1106.1	615.1	7899.0	2.4	274.5	1947.0	41.5	23.9	594.5	4822.8	27.7	7.9
3	21	Odwono	*Baphia nitida*	Papi	824.1	13129.8	0.0	0.0	56.2	0.0	29.7	0.0	14.7	0.0	0.0	0.0	0.0	0.0
3	22	Funtum	*Funtumia elastica*	Apoc	939.0	8232.7	2352.5	998.9	14374.8	2.2	476.1	3367.1	423.8	39.1	453.5	6261.7	81.6	7.4
3	23	Pepea	*Magaritaria discoidea*	Euph	558.2	10045.9	2918.6	264.5	5484.3	0.9	346.7	2342.6	115.3	23.4	804.9	4107.4	37.4	2.9
3	24	Tanuro	*Trichilia monadelpha*	Meli	523.0	9831.4	2293.8	1141.2	21203.0	6.4	418.8	2540.8	88.7	29.1	677.3	7388.9	156.7	2.5
3	26	Doma	*Ficus leprieuri*	Mora	745.2	26170.6	1630.5	773.4	18880.9	9.4	225.7	2229.7	37.8	29.7	1924.4	7464.9	125.2	30.3
3	27	Nyankyerene	*Ficus exasperata*	Mora	594.2	26892.6	2106.3	646.4	15851.8	6.2	217.5	5266.1	63.4	51.9	2065.2	11525.0	67.1	29.6
3	28	Afena	*Strombosia glaucescens*	Olac	480.1	7643.1	2205.8	387.1	9282.4	2.3	144.4	2257.0	366.9	25.4	674.3	4655.8	35.9	12.0
3	29	Pepea	*Magaritaria discoidea*	Euph	651.7	12762.7	5193.1	629.2	15521.5	2.8	253.7	3532.1	169.5	37.1	870.4	4788.8	102.0	14.6
3	30	Yaya	*Amphimas pterocarpoides*	Caes	396.9	12959.5	2354.4	814.7	8790.9	16.1	508.6	1749.8	42.1	17.3	734.6	4529.9	31.8	19.6
3	31	Pepea	*Magaritaria discoidea*	Euph	819.3	9235.5	2028.7	936.1	8973.2	14.9	371.4	1246.4	36.5	83.7	873.2	8628.9	60.2	11.7
3	33	Esafufuo	*Celtis mildbraedii*	Ulma	727.8	15071.6	2531.6	1496.7	34603.8	25.9	390.2	3789.8	25.4	77.8	1359.5	15171.2	206.3	26.8
3	34	Tanuro	*Trichilia monadelpha*	Meli	545.3	12773.3	3257.8	571.4	9057.8	16.3	197.6	3500.5	164.1	38.5	1540.4	5411.8	70.9	43.2
3	35	Tanuro	*Trichilia monadelpha*	Meli	653.9	14612.3	1735.2	992.4	12197.3	18.9	586.1	1765.1	60.9	28.2	891.6	5586.5	61.2	14.5
3	36	Pepea	*Magaritaria discoidea*	Euph	621.4	12704.2	3250.9	530.1	7174.3	20.3	197.7	3041.4	176.6	37.9	1445.4	5794.5	53.7	23.5
3	38	Dubrafo	*Mareya micrantha*	Euph	686.3	14244.3	2453.6	1171.2	20108.8	13.5	322.2	2254.2	69.2	28.6	760.4	24693.8	156.4	14.1
3	39	Pepea	*Magaritaria discoidea*	Euph	588.7	9722.3	4343.8	439.6	7534.9	10.4	148.5	2059.9	60.2	20.2	874.8	5130.2	52.1	10.8

3	40	Pepea	*Magaritaria discoidea*	Euph	679.2	15326.0	6540.7	711.9	11295.6	21.1	176.4	3577.2	89.4	45.4	1725.9	6542.7	80.8	20.7
3	41	Tanuronini	*Trichilia tessmanii*	Meli	844.3	17050.6	2028.0	658.0	6156.5	22.2	288.2	2514.4	38.5	55.4	1169.1	9061.2	31.7	17.7
3	42	Akye	*Blighia sapida*	Sapin	715.0	12246.6	1790.3	1101.1	17745.4	12.7	363.2	2451.1	34.5	28.1	1173.1	7059.7	119.3	15.3
3	43	Okro	*Albizia zygia*	Mimo	470.8	13823.1	2070.3	248.4	1779.5	12.5	150.4	1487.2	15.7	21.6	1140.5	4120.9	10.5	9.8
3	44	Nyankyerene	*Ficus capensis*	Mora	422.6	9378.4	1251.8	686.3	15659.8	11.4	186.3	2548.2	24.4	30.1	930.1	5535.6	99.8	14.3
3	46	Sinuro	*Alstonia boonei*	Apoc	451.8	15002.4	1661.9	431.3	4353.0	13.4	208.3	1994.4	23.9	28.5	1440.0	4173.2	18.8	18.7
3	47	Odwonkobire	*Baphia pubescens*	Papi	651.2	9639.8	3407.1	1072.9	11800.7	16.1	440.8	1694.4	525.8	30.5	860.5	10364.4	65.8	14.3
3	48	Sinuro	*Alstonia boonei*	Apoc	896.4	13555.4	1361.2	765.4	7102.4	17.3	378.7	3672.5	37.8	50.4	828.1	6978.0	34.4	13.1
3	49	Awiemfosamina	*Albizia ferruginea*	Mimo	895.5	5891.9	1192.7	406.8	2441.7	16.1	316.1	4035.7	49.3	50.0	601.1	7674.7	13.9	6.3
3	51	Kyenkyen	*Antiaris toxicaria*	Mora	946.4	13954.4	2174.4	737.6	11829.7	13.8	217.5	3216.8	89.0	39.4	996.5	13239.5	58.8	24.3
3	52	Sinuro	*Alstonia boonei*	Apoc	556.4	9850.9	1233.4	522.0	6404.0	10.9	185.6	2166.2	16.1	29.3	482.9	5375.9	24.1	9.6
3	53	Kakapenpen	*Rauvolfia vomitoria*	Apoc	791.6	20827.8	3851.7	704.1	3916.1	22.5	263.6	3264.7	88.3	49.9	1512.9	5909.5	23.6	32.5
3	54	Doma	*Ficus leprieuri*	Mora	1034.2	18673.2	2277.4	1010.9	18446.8	31.7	1200.6	2792.3	99.7	52.8	1085.3	10868.1	123.2	25.7
3	56	Doma	*Ficus leprieuri*	Mora	769.3	18311.4	1662.7	437.5	7583.1	0.0	248.2	2986.4	20.8	0.0	985.0	4602.6	47.1	11.4
3	58	Doma	*Ficus leprieuri*	Mora	809.2	33845.8	3995.5	4654.8	5674.3	26.9	982.8	4106.3	65.8	16.8	794.5	6103.7	50.8	51.9
3	59	Totro	*Anthonatha macrophylla*	Caes	824.6	12710.4	3831.9	700.7	7602.9	0.0	407.8	2224.5	43.4	0.0	1072.6	7516.5	35.6	17.5
2	62	Wawa	*Triplochiton scleroxylon*	Sterc	652.8	23652.7	3617.4	731.4	8031.6	0.0	404.4	2363.6	45.1	0.0	962.8	5386.4	45.5	5.8
2	63	Totro	*Anthonatha macrophylla*	Caes	606.5	5112.5	1067.1	687.3	12459.9	0.0	707.3	2216.5	39.3	0.0	714.6	5026.9	65.5	9.4
2	67	Tanuro	*Trichilia monadelpha*	Meli	880.5	23924.0	1842.2	875.2	7161.7	4.0	899.9	1844.9	38.0	0.0	1112.6	7584.7	39.0	14.6
2	68	Esakokoo	*Celtis zenkeri*	Ulma	824.6	26711.7	3604.3	1673.5	51009.5	8.4	372.9	5120.9	21.7	25.3	2425.4	16819.9	318.1	20.5
2	69	Cocoa	*Theobroma cacao*	Sterc	893.2	12661.6	1973.0	837.2	12943.4	0.8	290.0	6215.5	125.6	33.9	914.5	21231.0	110.5	11.1
2	70	Hotrohotro	*Hannoa klaineana*	Sima	565.7	13854.2	2354.6	6665.1	6748.1	0.0	367.0	5991.3	21.9	29.5	708.1	4271.2	25.8	7.9
2	71	Otie	*Pycnanthus angolensis*	Myris	634.0	5253.5	1495.7	838.0	12071.8	0.3	693.9	2857.5	100.5	2.9	575.4	4093.7	59.7	8.3
2	72	Tanuro	*Trichilia monadelpha*	Meli	815.6	10682.6	2962.3	1171.8	22038.9	4.9	347.1	1668.1	56.1	0.0	845.3	9061.1	170.4	7.3
2	73	Tanuro	*Trichilia monadelpha*	Meli	577.8	7511.8	2405.2	907.9	15042.5	1.4	400.2	1944.5	34.8	0.0	882.8	4981.3	93.8	43.6
2	74	Otie	*Pycnanthus angolensis*	Myris	765.5	10347.4	1806.0	775.7	8631.2	0.0	386.3	4816.1	122.4	16.1	730.9	4918.7	48.8	11.0
2	75	Tanuro	*Trichilia monadelpha*	Meli	583.3	6273.8	1452.9	662.5	10673.7	0.0	273.6	1518.9	20.8	0.0	617.5	5242.7	65.4	3.4
2	77	Tanuro	*Trichilia monadelpha*	Meli	723.9	10073.8	1488.6	602.6	8630.8	2.2	220.9	1115.5	16.6	0.0	734.4	6184.9	69.7	5.8
2	78	Tanuro	*Trichilia monadelpha*	Meli	766.1	16672.9	1726.3	722.3	5538.1	0.0	462.1	1422.1	26.7	0.0	974.6	5021.7	45.5	8.2
2	79	Wawabema	*Sterculia rhinopetala*	Sterc	441.1	34220.9	1998.3	302.7	5317.4	17.7	178.7	381.8	61.6	28.9	2499.7	3246.1	33.5	39.0
2	80	Esafufuo	*Celtis mildbraedii*	Ulma	699.6	24775.2	4367.7	704.8	8066.6	8.7	301.1	1527.9	141.9	10.4	1203.2	5245.1	20.7	18.4
2	81	Dubinfufuo	*Lovoa trichilioides*	Meli	496.1	18615.6	6267.9	1161.4	19039.3	17.2	314.7	3151.2	319.6	34.1	744.3	13117.4	123.6	11.3
2	83	Kakapenpen	*Rauvolfia vomitoria*	Apoc	902.3	35660.0	2891.5	188.8	2163.7	16.8	189.0	3218.0	73.3	27.8	1842.7	4933.0	5.7	20.3
2	84	Wawa	*Triplochiton scleroxylon*	Sterc	650.6	34319.3	2417.0	1000.6	24488.1	8.8	173.2	6325.3	81.0	64.6	863.2	8392.8	18040.1	12.2
2	86	Danta	*Nesogordonia papaverifera*	Sterc	644.1	15032.8	1417.9	275.3	5052.9	6.6	151.7	2027.5	137.4	18.3	486.7	3712.6	35.5	11.3
2	88	Tanuro	*Trichilia monadelpha*	Meli	648.0	7118.2	2919.8	533.2	956.6	12.8	334.7	876.4	65.4	11.2	737.9	7065.6	0.0	17.9

2	89	Yaya	*Amphimas pterocarpoides*	Caes	947.0	18848.8	3636.7	528.9	9926.7	13.1	227.2	2648.8	81.9	26.2	1386.7	6994.7	44.4	15.1
2	90	Wawa	*Triplochiton scleroxylon*	Sterc	595.8	19676.4	1792.3	378.2	5962.0	8.8	212.3	3356.6	167.8	29.0	922.3	3943.2	29.3	14.1
2	91	Anansedodowaa	*Cola millenii*	Sterc	540.9	14847.2	2431.2	774.4	13225.4	5.1	234.8	2630.4	75.4	22.0	494.8	6221.5	101.5	8.5
2	92	Tanuro	*Trichilia monadelpha*	Meli	624.6	16135.6	2936.9	690.5	14069.0	7.6	214.9	3242.9	89.8	27.0	1114.4	5499.9	80.1	14.2
2	94	Hotrohotro	*Hannoa klaineana*	Sima	627.3	7053.4	1261.0	574.0	5223.8	9.3	434.7	1279.7	162.7	17.7	387.5	5237.8	24.9	10.1
2	97	Funtum	*Funtumia elastica*	Apoc	870.9	9836.7	1784.5	804.0	10841.7	7.4	341.4	2947.8	92.4	29.4	657.3	6758.5	35.8	17.3
1	100	Tanuro	*Trichilia monadelpha*	Meli	732.4	6366.3	0.0	349.9	4033.4	2.9	162.2	756.6	91.3	6.4	260.2	3318.7	30.0	17.3
2	101	Odwonkobire	*Baphia pubescens*	Sapin	947.5	13363.8	2534.9	1499.4	38726.8	16.3	1058.2	3669.5	93.3	39.7	936.4	11610.3	237.0	23.8
1	102	esafufuo	*Celtis mildbraedii*	Ulma	670.3	19960.6	2270.4	1347.6	27156.0	20.1	328.0	2410.2	124.0	30.9	625.6	9281.6	147.7	16.0
1	103	Tanuro	*Trichilia monadelpha*	Meli	1002.3	6921.3	3097.5	737.0	17311.1	5.7	198.9	2975.6	82.9	30.2	820.1	5713.1	121.2	15.1
1	104	Kumnini	*Lannea welwitschii*	Anac	608.3	6898.3	2242.7	1065.1	24998.1	13.5	350.6	2585.0	86.1	25.2	743.3	4629.0	155.8	13.0
2	106	Pepea	*Magaritaria discoidea*	Euph	418.8	13102.4	1771.9	477.9	4352.7	7.8	179.1	2199.6	263.6	18.1	460.8	4017.9	29.4	11.7
1	108	Kakapenpen	*Rauvolfia vomitoria*	Apoc	952.3	20934.2	4397.9	775.7	13796.6	15.6	319.3	4067.0	101.5	40.8	1531.3	8543.2	76.4	19.7
1	109	Esakokoo	*Celtis zenkeri*	Ulma	933.7	20969.7	2876.7	1277.5	24496.0	5.2	335.1	2683.8	204.1	20.2	552.7	8470.0	172.0	8.4
1	112	Tanuro	*Trichilia monadelpha*	Meli	661.5	6517.0	1156.3	736.5	7768.9	5.5	606.9	3721.7	272.3	29.3	419.6	3896.4	29.7	13.1
1	113	Otie	*Pycnanthus angolensis*	Myris	439.8	5124.9	2446.6	969.8	12072.1	11.3	374.5	4207.2	152.8	39.3	663.1	8720.5	104.0	12.8
1	114	Tanuro	*Trichilia monadelpha*	Meli	902.8	6969.2	4083.6	1002.3	22916.9	14.0	372.1	8311.6	170.6	70.5	1563.7	6888.5	163.0	31.8
1	115	Nakwa	*Holoptelea grandis*	Ulma	1078.4	23918.7	2513.0	994.8	13666.3	9.5	607.4	4015.8	111.4	34.1	1936.4	7083.9	101.1	33.0
1	116	Wonton	*Morus mesozygia*	Mora	907.1	24014.5	2053.0	1127.0	15265.0	8.8	358.7	3006.6	79.9	56.2	630.2	8897.3	117.2	19.8
2	117	Mahogany	*Khaya ivorensis*	Meli	749.6	5554.1	2260.8	505.5	8649.7	9.6	358.0	2929.1	118.0	30.9	1020.4	6641.9	70.8	32.3
2	119	Wawabema	*Sterculia rhinopetala*	Sterc	1086.9	18859.4	3355.9	707.0	13314.4	8.8	269.9	2404.2	88.3	31.4	1195.9	6852.0	82.6	21.8
1	120	Kumnini	*Lannea welwitschii*	Anac	937.7	10662.2	1668.7	355.6	4745.5	12.7	152.6	2825.4	61.7	32.0	919.4	6133.9	16.4	39.1
2	121	Sinuro	*Alstonia boonei*	Apoc	793.6	18522.5	2039.6	1969.0	29211.0	12.5	420.0	3432.4	107.2	39.9	588.0	28449.0	260.9	16.1
2	122	Wawa	*Triplochiton scleroxylon*	Sterc	874.6	14560.8	2938.1	992.0	17291.3	5.2	312.6	2252.0	88.7	15.6	597.5	5500.2	157.3	26.5
2	123	Kaakaadikro	*Trichilia prieuriana*	Meli	815.0	12932.9	2352.2	523.9	10756.5	15.4	399.4	2373.1	135.8	30.3	1138.4	7624.3	32.3	29.1
2	124	Oyaa	*Zanthoxylum leprieurii*	Ruta	504.3	10651.4	2736.3	894.6	10960.4	10.5	320.9	3422.2	89.7	34.8	499.2	21304.1	93.1	13.4
2	125	Nyakomanini	*Myrianthus libericus*	Mora	455.3	15924.5	2476.0	731.2	10209.5	7.8	289.0	1747.6	666.0	15.3	527.4	7215.0	78.1	11.7
1	126	Odwono	*Baphia nitida*	Papi	662.7	8303.0	201.3	1893.0	25038.1	84.2	45.1	588.2	0.0	0.0	0.0	3578.9	70.6	34.5
1	127	Tanuro	*Trichilia monadelpha*	Meli	573.7	13313.3	2447.5	1293.7	28232.5	91.2	331.9	129.9	0.0	6.0	1328.2	5784.3	20.1	42.2
1	128	Tanuro	*Trichilia monadelpha*	Meli	524.9	9589.3	1532.9	1655.3	14111.4	92.7	211.6	410.1	0.0	55.4	945.9	6827.2	42.4	42.1
1	130	Okure	*Trilepisium madagascariense*	Mora	1074.6	12805.2	1108.7	1999.3	14578.9	105.1	1826.4	125.8	225.9	27.9	922.3	17440.9	76.9	51.1
1	132	Tanuro	*Trichilia monadelpha*	Meli	1136.9	7171.4	1089.2	2722.9	1842.6	112.9	110.0	734.1	0.0	0.0	1395.2	4851.1	130.6	50.4
1	133	Tanuro	*Trichilia monadelpha*	Meli	675.1	14406.6	2373.8	2026.2	14281.0	111.2	363.5	181.5	0.0	1.6	2048.0	6149.7	73.7	51.0
1	135	Dubinkokoo	*Entandrophragma angolense*	Meli	491.7	3841.8	1666.5	1416.0	14969.8	79.3	139.8	139.6	0.0	2.9	490.0	5070.7	27.9	35.1
1	137	Tanuro	*Trichilia monadelpha*	Meli	632.3	14842.8	1390.9	1395.2	7543.8	73.2	518.4	108.2	0.0	18.9	1877.0	6208.1	61.6	37.1
1	138	Okro	*Albizia zygia*	Mimo	575.6	6660.0	1079.2	1608.5	2637.4	69.4	94.3	298.5	10.6	0.0	1213.0	3416.3	76.8	31.5

1	139	Onyina	*Ceiba pentandra*	Bomb	624.6	13012.7	2133.4	2029.6	21366.3	106.2	216.9	210.9	0.0	13.0	2073.5	10762.5	57.0	51.3
1	140	Funtum	*Funtumia elastica*	Apoc	804.2	11313.9	1563.5	1685.6	10837.4	92.7	289.9	223.0	130.9	8.2	1009.9	5148.4	62.2	42.7
1	141	Dubinkokoo	*Entandrophragma angolense*	Meli	822.8	3733.3	2267.7	1234.6	29256.7	85.3	227.8	144.0	0.0	22.6	863.6	21777.0	7.0	42.2
1	142	Doma	*Ficus leprieuri*	Mora	1185.3	60328.8	4762.9	1931.1	8668.6	96.5	484.9	1911.7	0.0	55.3	7551.8	9542.8	91.5	63.0
1	144	Funtum	*Funtumia elastica*	Apoc	1030.5	5894.6	2479.6	2012.5	12915.9	107.8	261.2	579.0	219.5	44.1	1654.7	7505.9	82.8	51.6
1	145	Tanuro	*Trichilia monadelpha*	Meli	839.7	6078.1	2281.2	1334.3	24584.4	84.5	748.3	107.6	111.8	22.2	1317.2	8041.0	15.6	43.3
1	146	Odwonkobire	*Baphia pubescens*	Sapin	812.4	6187.2	1971.8	2221.2	11318.3	109.2	199.9	123.8	0.0	29.8	643.0	4996.5	78.3	50.4
1	147	Ownamdua	*Maesopsis eminii*	Rham	626.9	20020.9	2650.3	1649.1	5911.9	87.2	295.3	105.3	454.7	34.2	3535.6	6165.5	90.8	54.0
1	148	Doma	*Ficus leprieuri*	Mora	1023.6	36431.4	3733.0	2086.8	11512.1	95.3	327.8	1120.1	0.0	60.8	8372.0	7542.7	71.5	62.6
1	149	Akyebire	*Blighia unijugata*	Sapin	759.2	6554.2	2372.8	1755.1	16966.3	102.7	379.5	125.3	0.0	215.2	1536.2	10769.0	51.9	54.1
1	151	Foto	*Glyphaea brevis*	Tili	903.5	14275.3	2827.5	1715.6	11126.0	81.4	184.6	724.9	183.8	66.5	4192.4	6062.7	55.5	56.7
1	152	Otie	*Pycnanthus angolensis*	Myris	1030.0	6958.6	1280.7	2206.3	8032.5	97.6	205.6	132.6	305.2	60.3	1467.1	5369.2	106.9	53.8
1	153	Okro	*Albizia zygia*	Mimo	787.4	13933.1	242.0	2606.2	39.1	86.7	26.5	1301.8	0.0	2745.8	783.1	0.0	133.1	51.6
1	157	Okro	*Albizia zygia*	Mimo	668.2	11720.0	1797.5	2234.2	2231.7	70.9	104.6	654.1	0.0	4320.3	3151.6	26913.9	121.9	55.8
1	158	Okro	*Albizia zygia*	Mimo	814.3	15770.0	440.6	1485.6	1665.0	44.1	79.9	323.5	0.0	3756.3	2674.3	13813.3	90.9	42.3
1	160	Tanuro	*Trichilia monadelpha*	Meli	736.3	8458.8	2068.3	798.9	15148.5	11.5	302.9	1908.7	91.8	14.5	788.4	5059.3	86.2	10.5

Inventory and total element concentrations (mg kg^{-1}) of barks of tree species in Akyaakrom Secondary Forest

Plot	**Tree**			**Family**	Element (mg kg^{-1})													
No	**No**	**Local Name**	**Scientific Name**	**Name**	**Na**	**K**	**S**	**Al**	**Ca**	**Cu**	**Fe**	**Mg**	**Mn**	**Mo**	**P**	**Si**	**Sr**	**Zn**
3	1	Sinuro	*Alstonia boonei*	Apoc	419.7	13502.2	767.1	691.2	20743.6	4.1	156.0	1260.8	80.0	14.3	378.7	3435.0	166.3	5.0
3	2	Pepea	*Magaritaria discoidea*	Euph	398.1	6734.2	2651.4	642.7	19764.6	1.3	118.9	456.5	113.7	5.7	238.1	2637.7	149.4	15.6
3	3	Sofo	*Sterculia tragacantha*	Sterc	294.7	12246.6	1656.5	1134.5	38948.9	2.3	115.0	2335.6	113.7	33.3	241.4	4538.5	216.3	23.2
3	5	Pepea	*Magaritaria discoidea*	Euph	423.5	7235.2	1727.6	2130.6	75572.0	0.0	124.6	825.0	76.5	35.2	652.8	3156.7	386.6	3.9
3	7	Akyebire	*Blighia unijugata*	Sapin	281.1	6277.6	3029.3	718.2	18590.9	2.1	115.9	486.2	112.3	26.8	505.8	3487.1	81.3	22.4
3	8	Tanuro	*Trichilia monadelpha*	Meli	399.5	7761.9	2633.6	1420.4	45438.5	0.0	136.1	1476.0	83.5	38.9	398.4	3976.7	131.1	9.9
3	9	Okro	*Albizia zygia*	Mimo	487.2	5532.8	3509.9	1070.9	34265.6	0.0	130.7	1086.5	71.6	32.0	307.0	2671.7	227.7	105.4
3	10	Pepea	*Magaritaria discoidea*	Euph	372.0	10666.6	3895.0	851.6	27193.5	0.0	106.4	1339.3	127.8	31.1	385.6	2586.2	187.4	83.8
3	11	Dubrafo	*Mareya micrantha*	Euph	275.9	7976.2	2214.8	1192.9	41942.9	0.3	121.1	2239.5	59.3	42.3	241.0	4246.4	252.9	0.8
3	12	Domini	*Ficus capensis*	Mora	335.2	22831.7	3659.6	1679.8	59532.8	3.0	118.7	1302.0	77.0	35.7	429.3	3611.1	430.1	25.0
3	13	Tanuro	*Trichilia monadelpha*	Meli	430.4	5058.8	2503.9	1845.8	64941.5	5.3	119.2	1252.6	81.8	40.5	346.1	2881.0	181.6	9.4
3	14	Wawa	*Triplochiton scleroxylon*	Sterc	283.0	13358.5	3344.2	1317.0	44291.8	0.8	112.9	1103.2	100.5	35.2	367.1	3254.5	163.8	0.0
3	15	Okro	*Albizia zygia*	Mimo	183.1	3554.6	3620.9	536.1	15203.9	0.0	124.5	389.1	118.1	25.4	296.7	2635.3	47.4	20.4
3	16	Funtum	*Funtumia elastica*	Apoc	538.4	6144.6	2268.6	955.1	25991.6	2.9	164.7	1279.2	117.2	38.9	338.5	3115.2	152.6	44.4
3	17	Doma	*Ficus leprieuri*	Mora	302.4	21541.6	4004.5	1305.0	41685.8	6.0	140.0	1821.3	73.5	46.1	575.8	9253.1	322.9	59.4

3	18	Nwama	*Ricinodendron heudelotii*	Euph	337.8	26568.1	3082.2	1010.5	30370.4	2.4	131.0	8441.5	158.6	101.9	522.0	3697.1	219.3	18.0
3	20	Sinuro	*Alstonia boonei*	Apoc	314.8	5630.3	664.2	590.8	13707.2	0.0	152.9	987.2	69.7	33.5	270.6	2380.2	92.7	7.5
3	21	Odwono	*Baphia nitida*	Papi	360.2	5644.5	3014.2	1544.9	46123.2	2.2	190.1	1497.2	134.8	49.1	303.2	3254.1	350.2	23.4
3	22	Funtum	*Funtumia elastica*	Apoc	259.8	3152.5	1446.1	774.6	22567.1	0.9	110.6	1012.5	110.3	21.9	258.1	2235.5	157.3	11.9
3	23	Pepea	*Magaritaria discoidea*	Euph	227.7	6059.5	2305.3	1051.1	34428.9	6.4	126.5	1100.4	128.2	27.6	316.5	2111.4	215.4	21.4
3	24	Tanuro	*Trichilia monadelpha*	Meli	244.3	4916.6	1796.2	1087.5	36062.3	9.4	100.7	1085.1	154.2	90.9	247.3	2275.9	96.9	6.4
3	26	Doma	*Ficus leprieuri*	Mora	474.5	16018.5	3853.4	2253.9	79624.5	2.3	144.7	746.9	78.8	28.9	393.2	15284.3	560.0	44.6
3	27	Nyankyerene	*Ficus exasperata*	Mora	615.5	23248.4	2036.5	1820.3	62589.1	2.8	142.6	3185.5	92.7	46.7	482.3	9890.2	509.1	12.3
3	28	Afena	*Strombosia glaucescens*	Olac	327.2	5195.9	1940.0	1419.4	49703.4	16.1	101.5	1434.7	69.7	31.1	342.5	2283.6	136.3	1.4
3	29	Pepea	*Magaritaria discoidea*	Euph	286.4	7984.4	2162.9	702.3	19640.1	14.9	120.3	756.4	68.3	31.5	509.6	2407.8	150.4	7.9
3	30	Yaya	*Amphimas pterocarpoides*	Caes	385.2	13427.7	6202.4	1856.8	60550.6	25.9	160.0	3763.8	79.1	60.3	458.6	2676.3	367.7	22.4
3	31	Pepea	*Magaritaria discoidea*	Euph	404.3	9363.2	4002.3	1137.2	31935.7	16.3	175.1	1737.5	168.9	36.8	364.4	4126.2	237.9	35.5
3	33	Esafufuo	*Celtis mildbraedii*	Ulma	329.8	4761.9	1897.9	1554.2	54712.8	20.3	131.6	1151.5	75.3	33.2	333.4	5401.1	339.9	1.9
3	34	Tanuro	*Trichilia monadelpha*	Meli	245.3	4994.4	2383.6	1541.9	54402.1	13.5	137.1	1818.2	85.6	37.1	341.8	2296.8	137.2	2.7
3	35	Tanuro	*Trichilia monadelpha*	Meli	420.8	24376.2	1913.2	1494.8	48818.1	10.4	134.1	1185.3	81.8	34.1	585.0	5788.1	320.7	5.5
3	36	Pepea	*Magaritaria discoidea*	Euph	362.6	11291.7	4214.2	768.9	22072.1	21.1	120.4	944.8	164.0	29.3	308.7	2217.3	164.0	36.5
3	38	Dubrafo	*Mareya micrantha*	Euph	511.3	10666.6	885.9	1268.0	40900.7	12.7	146.0	2002.3	222.3	40.4	446.3	8142.7	254.9	1.5
3	39	Pepea	*Magaritaria discoidea*	Euph	414.4	7182.0	2613.1	1045.2	33284.6	12.5	125.1	703.0	93.4	28.2	332.7	2517.7	204.3	23.5
3	40	Pepea	*Magaritaria discoidea*	Euph	452.7	7352.2	2671.8	1055.3	33839.8	11.4	110.9	983.2	103.3	33.0	343.2	2695.2	213.7	21.8
3	41	Tanuronini	*Trichilia tessmanii*	Meli	242.7	6852.8	2558.2	1389.2	46852.2	13.4	74.2	1769.3	38.3	28.6	312.3	1454.8	129.4	12.6
3	42	Akye	*Blighia sapida*	Sapin	228.8	3871.6	2487.1	2178.8	67839.3	16.1	84.0	1232.5	18.2	36.4	405.7	2254.3	464.7	13.9
3	43	Okro	*Albizia zygia*	Mimo	438.9	9746.2	3280.2	1681.1	42853.8	17.3	120.7	981.8	75.2	45.6	499.6	2796.8	255.7	63.3
3	44	Nyankyerene	*Ficus capensis*	Mora	348.5	25833.9	1772.8	1705.4	43850.0	16.1	115.7	1505.3	27.1	49.1	822.2	4971.3	334.0	11.9
3	46	Sinuro	*Alstonia boonei*	Apoc	342.3	7820.4	657.5	938.7	15425.7	13.8	159.9	987.3	27.0	42.2	375.5	3412.4	137.7	30.9
3	47	Odwonkobire	*Baphia pubescens*	Papi	629.4	8698.2	2465.8	1081.7	21848.7	10.9	136.6	960.7	135.4	56.1	366.0	2949.9	92.5	23.9
3	48	Sinuro	*Alstonia boonei*	Apoc	235.9	3356.0	538.7	755.0	10795.3	22.5	213.6	821.5	23.6	48.2	370.7	2280.6	68.2	10.0
3	49	Awiemfosamina	*Albizia ferruginea*	Mimo	486.8	10969.8	2790.3	1040.9	21820.9	31.7	107.0	5835.7	64.2	99.5	479.9	2942.9	150.5	10.6
3	51	Kyenkyen	*Antiaris toxicaria*	Mora	329.0	26050.3	1423.9	785.4	13164.5	0.0	136.5	1609.6	77.1	59.1	552.6	7899.1	92.2	26.6
3	52	Sinuro	*Alstonia boonei*	Apoc	393.7	4265.8	647.3	767.5	10735.3	268.8	204.6	1525.1	25.5	55.2	367.8	2463.1	79.0	17.2
3	53	Kakapenpen	*Rauvolfia vomitoria*	Apoc	295.3	5151.5	3109.5	1242.4	24843.7	0.0	168.2	1753.5	114.8	57.9	363.7	2876.0	177.5	36.2
3	54	Doma	*Ficus leprieuri*	Mora	346.2	10037.1	2164.1	1731.7	44255.1	0.0	122.7	1271.2	35.9	60.7	529.2	5014.6	314.5	29.7
3	56	Doma	*Ficus leprieuri*	Mora	458.1	17183.6	1792.0	1465.1	34830.6	0.0	110.7	1116.7	33.8	58.3	405.0	5703.6	237.4	23.5
3	58	Doma	*Ficus leprieuri*	Mora	329.8	7565.0	1836.1	1490.2	34873.7	8.4	192.5	1494.0	31.3	71.1	526.4	19667.0	267.8	39.3
3	59	Totro	*Anthonatha macrophylla*	Caes	242.1	9352.6	1907.5	1215.0	24507.7	0.8	138.2	675.5	200.4	65.8	390.3	2886.2	84.2	19.0
2	62	Wawa	*Triplochiton scleroxylon*	Sterc	229.8	10448.5	3234.0	3211.5	43992.0	4.9	460.5	1497.5	33.7	78.6	385.7	5100.0	169.2	10.1
2	63	Totro	*Anthonatha macrophylla*	Caes	262.5	7700.7	1036.1	1446.2	35650.8	1.4	128.0	1854.8	30.8	48.0	385.3	2840.2	164.4	25.5

2	67	Tanuro	*Trichilia monadelpha*	Meli	286.9	5415.0	1927.3	1574.5	45964.2	2.2	71.3	1066.5	23.9	38.3	342.9	2170.0	134.8	6.8
2	68	Esakokoo	*Celtis zenkeri*	Ulma	237.6	10405.0	1934.5	1443.0	35509.0	0.0	88.2	1181.6	15.1	46.5	404.4	3042.0	280.5	8.3
2	69	Cocoa	*Theobroma cacao*	Sterc	254.0	15968.9	2392.1	1387.9	33480.4	17.7	97.0	1188.4	63.5	48.5	207.5	2341.5	186.9	14.6
2	70	Hotrohotro	*Hannoa klaineana*	Sima	450.6	23897.4	1613.5	1217.4	25068.5	8.7	163.5	2272.4	21.8	64.5	362.6	2940.3	87.1	7.1
2	71	Otie	*Pycnanthus angolensis*	Myris	383.8	6327.0	2931.7	1267.1	31076.6	17.2	106.3	1850.8	185.1	49.1	326.2	2077.0	236.3	50.8
2	72	Tanuro	*Trichilia monadelpha*	Meli	281.6	3837.1	1654.3	1612.1	46501.1	16.8	66.5	904.0	18.2	39.7	233.9	1924.9	162.6	5.1
2	73	Tanuro	*Trichilia monadelpha*	Meli	262.8	17146.4	1374.2	1096.2	22768.6	8.8	121.1	6967.0	90.7	108.5	258.6	2925.1	144.7	7.6
2	74	Otie	*Pycnanthus angolensis*	Myris	278.2	14010.6	1002.7	988.0	20175.9	6.6	116.4	4486.2	90.3	73.7	223.9	2549.8	140.3	5.2
2	75	Tanuro	*Trichilia monadelpha*	Meli	293.7	5601.2	1654.4	764.4	14749.8	12.8	95.8	566.0	64.6	39.0	209.7	2100.5	62.5	9.5
2	77	Tanuro	*Trichilia monadelpha*	Meli	323.6	5727.9	1892.3	1708.0	47741.2	13.1	72.0	1284.4	18.1	51.6	367.6	2591.1	149.7	5.7
2	78	Tanuro	*Trichilia monadelpha*	Meli	303.2	6687.2	2380.1	1776.1	43170.4	8.8	105.3	1414.0	31.7	60.4	342.7	2492.9	153.9	5.7
2	79	Wawabema	*Sterculia rhinopetala*	Sterc	231.4	21847.5	457.2	765.3	14053.3	5.1	99.8	3951.8	25.8	73.8	318.1	2201.5	112.5	12.0
2	80	Esafufuo	*Celtis mildbraedii*	Ulma	321.3	10485.7	1939.1	1827.7	43946.1	7.6	126.7	1902.0	20.2	69.6	389.1	4005.1	325.2	9.6
2	81	Dubinfufuo	*Lovoa trichilioides*	Meli	336.3	13577.4	5983.9	1081.7	22260.2	3.6	123.0	1794.6	55.9	56.2	825.7	2315.9	53.4	10.5
2	83	Kakapenpen	*Rauvolfia vomitoria*	Apoc	307.7	6667.7	3118.9	1735.2	48762.3	7.4	162.8	885.8	133.2	32.0	310.9	2276.1	414.2	26.7
2	84	Wawa	*Triplochiton scleroxylon*	Sterc	309.1	17651.8	4033.1	947.3	21439.3	2.9	169.7	983.6	115.8	35.4	234.6	2086.9	88.3	3.7
2	86	Danta	*Nesogordonia papaverifera*	Sterc	337.8	5789.9	6783.5	1452.8	35939.9	20.1	141.4	3393.0	146.5	59.9	330.7	2366.6	100.1	72.7
2	88	Tanuro	*Trichilia monadelpha*	Meli	365.0	7155.4	2490.9	1815.7	44963.5	13.5	173.5	1362.7	117.3	42.8	361.4	2540.0	134.9	7.0
2	89	Yaya	*Amphimas pterocarpoides*	Caes	295.8	6447.8	3367.2	1421.9	33535.6	7.8	199.7	433.2	165.7	36.7	345.0	2223.2	213.3	23.4
2	90	Wawa	*Triplochiton scleroxylon*	Sterc	332.5	13113.8	6703.0	1472.3	34460.4	15.6	178.6	2905.3	123.8	63.0	244.7	2550.9	107.2	5.6
2	91	Anansedodowaa	*Cola millenii*	Sterc	277.1	9873.0	735.7	1437.4	33965.8	5.2	166.3	8760.8	138.0	111.6	255.4	3033.5	125.5	5.6
2	92	Tanuro	*Trichilia monadelpha*	Meli	412.8	4791.7	1774.8	1556.3	34337.6	5.5	188.2	1482.6	126.4	48.4	370.5	2695.8	135.9	6.8
2	94	Hotrohotro	*Hannoa klaineana*	Sima	254.3	4511.9	2894.0	1310.6	29489.5	11.3	177.1	3286.9	142.8	65.6	354.3	3152.0	237.9	61.3
2	97	Funtum	*Funtumia elastica*	Apoc	383.5	6051.5	1454.3	1122.9	25179.9	8.8	154.0	1129.5	134.5	38.9	257.8	2123.7	176.5	12.5
1	100	Tanuro	*Trichilia monadelpha*	Meli	305.4	8208.8	2780.1	1690.7	38963.3	8.8	200.9	890.5	346.8	142.3	353.9	3071.0	165.3	22.4
2	101	Odwonkobire	*Baphia pubescens*	Sapin	227.2	3616.5	2370.3	1085.1	21588.4	12.7	169.6	965.0	94.7	37.1	194.0	2357.2	171.5	33.6
1	102	esafufuo	*Celtis mildbraedii*	Ulma	259.4	13308.9	1763.3	1340.3	31775.4	12.5	151.5	1594.4	96.8	45.3	333.4	1895.1	210.8	7.6
1	103	Tanuro	*Trichilia monadelpha*	Meli	278.0	3487.7	1003.5	1113.0	25414.3	5.2	175.8	798.8	103.0	49.0	258.4	2848.0	238.3	3.0
1	104	Kumnini	*Lannea welwitschii*	Anac	213.9	13528.0	2794.6	2231.2	67701.9	15.4	146.9	1747.1	92.6	46.6	266.4	2104.9	419.1	7.4
2	106	Pepea	*Magaritaria discoidea*	Euph	418.8	8842.6	1467.8	1244.5	28943.3	7.8	148.6	1875.6	87.2	43.1	292.6	4059.0	207.9	9.9
1	108	Kakapenpen	*Rauvolfia vomitoria*	Apoc	256.7	3238.6	2879.8	1600.4	30458.2	91.2	227.4	1319.0	213.5	44.1	297.6	2338.3	266.5	28.6
1	109	Esakokoo	*Celtis zenkeri*	Ulma	328.5	10959.2	1918.8	1814.3	50206.2	92.7	145.9	1948.6	108.8	49.5	333.7	2061.7	287.1	6.5
1	112	Tanuro	*Trichilia monadelpha*	Meli	227.2	3808.1	2408.2	1849.9	43788.7	111.2	184.0	1749.4	123.1	55.9	324.8	2501.4	129.6	8.7
1	113	Otie	*Pycnanthus angolensis*	Myris	258.0	6197.8	3349.8	1394.7	31823.0	79.3	155.2	1592.9	276.3	52.4	278.7	7530.1	119.1	5.2
1	114	Tanuro	*Trichilia monadelpha*	Meli	262.8	20013.8	2225.8	1954.7	46362.3	73.2	190.7	1661.9	133.9	56.7	530.4	15385.7	467.6	10.9
1	115	Nakwa	*Holoptelea grandis*	Ulma	493.2	8974.8	1794.1	1624.6	35305.6	69.4	203.7	959.6	121.0	48.6	296.3	2688.1	284.0	5.6

1	116	Wonton	*Morus mesozygia*	Mora	460.2	5612.6	1180.1	2089.3	56986.1	106.2	190.0	998.1	131.9	53.7	344.1	8136.5	461.2	6.8
2	117	Mahogany	*Khaya ivorensis*	Meli	524.5	9057.3	2064.6	1029.6	22097.2	92.7	146.5	1522.0	98.0	52.4	407.6	2478.9	155.3	16.1
2	119	Wawabema	*Sterculia rhinopetala*	Sterc	445.3	10703.8	3168.2	1909.8	45525.4	96.5	173.7	2244.1	128.3	67.5	312.4	2711.8	264.0	19.6
1	120	Kumnini	*Lannea welwitschii*	Anac	358.2	8037.6	2216.0	2225.2	60146.3	107.8	161.5	2228.3	99.2	66.1	367.6	3878.3	439.0	9.6
2	121	Sinuro	*Alstonia boonei*	Apoc	390.1	3917.7	541.3	564.1	7460.8	84.5	181.2	610.2	99.9	48.3	283.2	2157.0	47.1	10.9
2	122	Wawa	*Triplochiton scleroxylon*	Sterc	507.5	4992.8	6354.1	2839.7	70862.8	109.2	222.9	2193.5	145.4	88.3	551.6	2124.6	462.7	30.9
2	123	Kaakaadikro	*Trichilia prieuriana*	Meli	308.0	10719.8	4095.9	2100.0	45495.4	87.2	241.0	452.5	147.3	103.1	677.5	2200.8	156.4	32.7
2	124	Oyaa	*Zanthoxylum leprieurii*	Ruta	430.9	1798.6	884.7	1295.4	21117.1	95.3	181.1	299.0	125.7	141.0	667.8	1889.6	98.9	23.2
2	125	Nyakomanini	*Myrianthus libericus*	Mora	352.7	7639.5	1974.3	1067.6	6710.7	102.7	268.9	912.9	158.8	275.2	1456.6	12429.5	60.0	45.4
1	126	Odwono	*Baphia nitida*	Papi	398.2	3552.2	605.7	1229.8	7214.9	81.4	244.6	488.9	119.5	275.8	1716.0	1624.6	52.3	71.8
1	127	Tanuro	*Trichilia monadelpha*	Meli	423.5	5559.4	3110.9	2003.2	42789.7	97.6	230.8	1176.5	145.9	62.1	443.7	2668.3	169.0	12.4
1	128	Tanuro	*Trichilia monadelpha*	Meli	254.5	7567.7	2084.0	957.6	25628.7	86.7	181.7	1513.1	126.4	54.8	400.4	7219.5	192.1	42.7
1	130	Okure	*Trilepisium madagascariense*	Mora	435.2	5894.6	2978.0	1089.3	27227.2	44.1	200.8	1524.6	148.6	68.0	359.5	3810.6	157.5	5.9
1	132	Tanuro	*Trichilia monadelpha*	Meli	418.5	8893.3	2715.7	724.5	10611.0	29.2	182.5	592.1	195.6	53.2	438.9	2335.7	45.9	33.6
1	133	Tanuro	*Trichilia monadelpha*	Meli	383.4	2908.9	1974.3	1381.0	47143.6	24.4	138.0	1782.9	117.0	57.0	377.6	2000.2	122.7	10.9
1	135	Dubinkokoo	*Entandrophragma angolense*	Meli	237.2	11486.8	2885.6	1321.2	37119.0	30.8	174.8	1718.9	122.9	64.3	462.8	2377.2	234.6	8.3
1	137	Tanuro	*Trichilia monadelpha*	Meli	436.7	4355.3	2091.3	1354.0	44442.5	29.4	177.1	1641.9	124.0	63.2	351.2	2327.1	117.3	7.4
1	138	Okro	*Albizia zygia*	Mimo	246.1	3442.9	2377.1	1068.0	27722.1	29.8	186.4	245.3	161.4	51.9	342.6	2738.4	13131.5	21.9
1	139	Onyina	*Ceiba pentandra*	Bomb	282.5	10139.9	479.4	804.5	17479.1	34.6	203.6	2655.2	143.9	81.8	343.1	6.8	142.4	17.3
1	140	Funtum	*Funtumia elastica*	Apoc	627.8	5705.7	1995.1	1374.2	37119.2	30.8	178.7	1683.1	165.5	68.0	431.0	2821.9	239.7	56.2
1	141	Dubinkokoo	*Entandrophragma angolense*	Meli	260.1	5283.3	1957.6	1242.9	31203.9	37.2	202.8	1513.9	145.9	79.5	421.9	3383.1	245.9	12.1
1	142	Doma	*Ficus leprieuri*	Mora	317.0	17015.1	3316.5	1604.4	68141.9	31.8	178.8	981.8	127.0	62.7	525.8	2776.5	342.7	41.6
1	144	Funtum	*Funtumia elastica*	Apoc	260.7	5129.4	2419.7	1306.2	33681.5	31.5	200.7	1398.8	162.0	68.9	463.1	2151.8	246.1	31.7
1	145	Tanuro	*Trichilia monadelpha*	Meli	384.1	4781.6	1874.2	1535.2	41444.7	36.0	204.2	1109.1	161.2	75.1	402.1	2796.4	150.8	12.1
1	146	Odwonkobire	*Baphia pubescens*	Sapin	356.9	10139.0	4254.9	1372.8	37951.0	33.4	172.1	1461.5	123.7	68.8	345.3	2229.0	123.3	7.2
1	147	Ownamdua	*Maesopsis eminii*	Rham	572.4	8485.4	2564.1	572.5	6938.5	37.7	214.1	517.1	196.4	106.0	550.8	2859.0	34.2	33.7
1	148	Doma	*Ficus leprieuri*	Mora	247.8	16265.9	1801.0	1239.2	33694.7	30.7	180.3	1518.3	124.4	68.1	493.3	9333.9	252.8	19.5
1	149	Akyebire	*Blighia unijugata*	Sapin	296.6	9757.8	3347.7	1261.1	32041.7	32.0	180.1	2019.5	123.8	77.5	745.2	2512.7	150.1	20.7
1	151	Foto	*Glyphaea brevis*	Tili	345.8	11789.1	2312.0	1572.0	43459.2	37.4	202.4	1705.0	188.9	87.1	331.3	2845.2	269.5	24.0
1	152	Otie	*Pycnanthus angolensis*	Myris	350.7	15410.3	1277.1	948.2	22949.9	31.7	167.1	8521.5	283.7	129.8	346.1	2241.8	131.6	9.0
1	153	Okro	*Albizia zygia*	Mimo	359.6	4345.4	2230.2	1046.9	19917.0	38.0	229.8	476.2	190.3	72.9	435.0	2733.5	107.4	23.2
1	157	Okro	*Albizia zygia*	Mimo	393.7	4958.8	3324.7	900.7	17979.6	35.9	207.3	1047.3	147.6	79.3	481.0	2835.3	137.9	9.1
1	158	Okro	*Albizia zygia*	Mimo	212.8	15968.9	1941.3	1614.0	50731.3	30.4	179.8	954.4	120.5	68.1	319.4	2331.1	85.0	5.8
1	160	Tanuro	*Trichilia monadelpha*	Meli	264.7	5816.5	2578.2	1754.3	58399.0	31.3	172.6	1277.3	131.1	70.5	391.9	2165.8	150.5	9.8

Appendix D: Inventory and total element concentrations (mg kg^{-1}) of leaves of tree species in Dopiri Secondary Forest (DS)

Plot No.	Tree No.	Local Name	Scientific Name	Family Name	Elements (mg kg^{-1}) Na	K	S	Al	Ca	Cu	Fe	Mg	Mn	Mo	P	Si	Sr	Zn
3	1	Pepea	*Magaritaria discoidea*	Euph	782.6	10703.8	3477.8	823.0	10468.2	2.5	398.8	2438.5	405.9	23.0	1594.7	8783.7	58.0	20.6
3	2	Tanuro	*Trichilia monadelpha*	Meli	959.7	13374.5	1882.1	1821.7	25954.9	5.9	765.4	2843.0	122.7	68.7	722.5	11466.1	157.0	57.1
3	3	Pepea	*Magaritaria discoidea*	Euph	630.8	6824.8	2042.6	821.0	7045.0	4.1	509.2	2202.5	275.0	14.2	759.2	8835.5	55.4	11.5
3	4	Okro	*Albizia zygia*	Mimo	663.9	5405.1	1512.6	325.4	4118.3	4.6	207.2	1175.8	139.6	18.6	792.4	5915.5	19.0	7.1
3	5	Tanuro	*Trichilia monadelpha*	Mel	669.9	10786.3	1754.8	1250.6	26110.9	10.8	455.7	2202.3	64.5	20.3	650.6	9448.0	144.3	11.0
3	6	Wawa	*Triplochiton scleroxylon*	Sterc	1188.5	25174.2	2903.3	986.0	13862.9	5.5	347.9	2318.3	74.5	24.7	1028.8	12166.5	79.7	12.8
3	7	Funtum	*Funtumia elastica*	Apoc	592.3	19644.1	2292.3	421.8	8248.2	5.3	191.3	3216.4	101.3	30.9	1039.5	5205.5	42.9	14.0
3	8	Doma	*Ficus leprieuri*	Mora	740.4	20149.5	1743.4	425.0	8234.3	11.7	372.7	3535.1	28.9	34.6	1736.1	5834.2	63.3	26.4
3	9	Doma	*Ficus leprieuri*	Mora	865.4	28541.8	1913.1	887.3	27129.1	5.4	136.9	3947.4	30.7	38.3	1573.1	12973.4	185.9	9.3
3	10	Tanuro	*Trichilia monadelpha*	Meli	1066.7	13091.6	1509.4	1117.4	9661.5	9.2	533.9	1866.9	45.8	27.9	950.6	9141.3	55.8	14.4
3	11	Tanuro	*Trichilia monadelpha*	Meli	845.3	16140.9	2570.0	1392.0	18891.1	24.7	209.6	2292.0	1647.7	29.6	1469.5	7092.1	62.6	27.9
3	12	Doma	*Ficus leprieuri*	Mora	952.8	21120.4	1927.6	668.7	7635.0	29.5	237.4	2949.1	29.7	42.3	1965.7	9304.2	88.6	18.5
3	13	Okro	*Albizia zygia*	Mimo	734.6	11863.6	2323.6	530.8	4555.3	12.1	258.7	1678.8	45.7	28.5	1886.7	6805.0	22.3	30.1
3	16	Odwono	*Baphia nitida*	Papi	696.0	8210.5	1968.5	562.6	4786.9	11.0	315.4	1791.7	390.6	41.7	1356.3	7614.1	32.9	19.4
3	17	Odwono	*Baphia nitida*	Papi	816.6	7820.4	2102.5	521.3	3294.8	11.4	358.0	1409.9	114.7	24.6	1534.8	7468.0	24.2	19.3
3	18	Gyama	*Alchornea cordifolia*	Euph	1500.8	9368.5	2556.3	1459.2	16258.6	13.8	693.7	2083.7	367.9	53.5	1732.2	10030.1	102.9	19.1
3	19	Tanuro	*Trichilia monadelpha*	Meli	745.9	8272.6	1765.8	1175.5	19252.5	11.7	388.5	1862.9	61.7	54.8	822.2	10141.5	107.3	16.5
3	22	Sese	*Holarrhena floribunda*	Apoc	894.3	8549.2	1565.7	835.9	6515.0	13.2	447.7	4053.6	329.5	46.0	692.7	8525.2	24.5	16.1
3	24	Okro	*Albizia zygia*	Mimo	754.9	23466.5	1306.8	444.1	1503.9	9.1	281.9	1558.4	48.4	34.6	1917.5	7680.8	11.1	17.1
3	27	Dubrafo	*Mareya micrantha*	Euph	791.8	11624.2	2427.2	1155.4	24325.6	8.5	379.5	2109.6	64.3	432.2	629.5	26324.9	219.4	8.2
3	31	Sinuro	*Alstonia boonei*	Apoc	738.2	13415.3	1527.3	640.5	9962.0	10.8	223.3	4457.8	41.8	51.6	1014.3	8233.5	38.2	13.6
3	33	Yaya	*Amphimas pterocarpoides*	Caes	750.1	11101.1	1705.9	411.9	1134.1	10.8	235.0	1094.2	23.9	22.2	1186.0	7139.0	6.1	19.1
3	35	Opamfufuo	*Macaranga hurifolia*	Euph	796.2	18362.9	1809.4	495.9	8465.7	11.5	203.7	3081.5	87.6	40.3	1789.8	6844.6	52.8	35.6
3	36	Odwono	*Baphia nitida*	Papi	745.9	8746.1	1683.4	393.6	1592.6	19.6	244.7	1192.7	39.6	45.6	1750.9	7638.3	16.6	21.7
3	37	Sesemasa	*Newbouldia laevis*	Bign	790.5	20943.1	1946.2	588.8	4028.9	22.1	285.1	1798.2	27.0	31.6	1639.0	6440.0	20.1	23.9
3	38	Odwono	*Baphia nitida*	Papi	628.1	12574.2	2796.8	35.0	2052.8	16.9	235.7	1578.0	71.2	32.3	2907.8	4224.2	10.1	30.6
3	39	Tanuro	*Trichilia monadelpha*	Meli	663.2	11482.3	2252.3	1076.0	19610.9	11.2	336.8	1626.0	59.5	37.3	864.8	7335.7	98.5	12.4
2	40	Nyankyerene	*Ficus capensis*	Mora	747.5	28918.6	3223.8	1678.9	27226.7	11.9	383.6	5666.7	45.3	74.1	1989.5	24728.3	194.6	25.5
2	41	Sinuro	*Alstonia boonei*	Apoc	775.7	15412.0	1490.0	664.3	5578.1	12.1	307.7	3378.3	33.9	66.5	915.0	6117.9	23.8	13.0
2	42	Konkroma	*Morinda lucida*	Rubi	628.1	12034.6	1523.5	987.2	15168.5	8.6	373.6	1345.2	52.7	29.1	671.3	6027.0	81.4	9.4
2	43	Tanuro	*Trichilia monadelpha*	Meli	924.6	12576.5	1881.3	1733.1	31877.6	13.5	628.0	1555.0	116.5	55.2	931.9	12342.2	186.8	12.0

2	44	Odwono	*Baphia nitida*	Papi	1253.9	26488.3	1894.1	997.0	4941.1	13.5	525.9	1729.6	125.2	52.2	1143.2	7484.5	29.3	22.4
2	45	Okro	*Albizia zygia*	Mimo	770.1	8640.6	2129.7	435.1	5723.3	9.3	162.5	1775.8	245.7	38.2	1206.0	5054.9	29.6	12.7
2	46	Gyama	*Alchornea cordifolia*	Euph	698.7	7394.8	1216.9	361.8	4374.5	12.2	134.0	1221.2	74.5	99.9	1219.8	5536.9	30.3	16.8
2	47	Nseduansehoma	*Castonala paradoxa*	Conn	859.2	22620.6	2416.6	667.3	5174.1	13.4	292.5	2408.4	50.0	47.9	1814.5	7453.1	29.3	26.5
2	49	Odwonkobire	*Baphia pubescens*	Papi	866.3	9868.6	2877.4	1032.5	8972.7	12.1	530.8	1962.4	206.0	58.6	907.4	8773.3	68.4	18.4
2	50	Konkroma	*Morinda lucida*	Rubi	816.1	21929.0	2708.7	1274.1	10495.6	23.6	388.4	4065.9	535.3	64.6	1822.3	7057.6	34.7	46.7
2	51	Okro	*Albizia zygia*	Mimo	586.7	6353.6	1794.2	425.1	6102.3	9.1	164.7	2087.1	192.6	37.1	976.0	4101.7	34.8	7.8
2	52	Okro	*Albizia zygia*	Mimo	578.1	10728.7	1542.4	708.0	4634.9	11.1	367.8	1165.7	35.1	29.1	760.1	6055.7	25.9	12.0
2	53	Doma	*Ficus leprieuri*	Mora	997.5	23838.9	2838.5	1237.9	10340.4	11.9	376.7	4316.8	608.7	64.5	2038.3	5915.4	52.7	48.0
2	54	Gyama	*Alchornea cordifolia*	Euph	1130.5	18482.6	1620.3	880.6	4524.0	10.2	251.7	2766.6	357.8	51.8	1146.6	5811.5	30.7	22.1
2	55	Konkroma	*Morinda lucida*	Rubi	848.5	31329.5	2828.5	1028.6	5673.4	19.3	355.7	2231.5	425.7	47.2	1956.0	5369.2	31.5	21.8
2	56	Konkroma	*Morinda lucida*	Rubi	819.8	21354.5	1982.8	747.7	10372.9	14.1	269.6	6159.2	52.7	83.6	2090.8	8650.6	99.8	34.4
2	57	Doma	*Ficus leprieuri*	Mora	935.4	15073.3	1962.1	389.4	984.7	9.2	202.5	804.3	22.9	27.8	1297.6	5072.5	5.8	10.3
2	58	Okro	*Albizia zygia*	Mimo	842.3	13082.8	1808.7	377.5	1406.8	9.6	213.5	938.2	21.3	79.9	1084.3	4952.2	6.3	14.1
2	60	Okro	*Albizia zygia*	Mimo	818.7	10975.2	2583.7	543.2	7235.1	15.5	218.6	2841.1	256.1	55.3	1411.4	5605.6	40.5	12.2
2	61	Gyama	*Alchornea cordifolia*	Euph	737.2	6942.6	1253.5	724.5	8579.0	5.3	384.3	1645.5	90.7	20.2	831.5	5274.3	64.6	8.2
2	62	Kyenkyen	*Antiaris toxicaria*	Mora	862.7	21031.7	1488.8	1500.3	4885.3	6.6	890.7	2836.4	70.3	36.0	1502.3	5999.1	35.6	12.7
2	63	Kyereye	*Pterygota macrocarpa*	Sterc	981.2	11954.8	1682.9	714.7	20242.1	3.4	128.6	2575.1	46.1	28.0	655.3	13146.5	159.9	13.3
2	65	Domini	*Ficus capensis*	Mora	1151.8	5575.4	1560.8	1102.8	23163.9	4.2	292.7	3919.8	276.4	43.3	790.9	8635.1	136.4	18.7
2	66	Avocado	*Persea americana*	Laur	1048.9	8449.9	1567.3	924.0	14771.7	1.6	320.1	3060.7	118.1	30.6	952.9	6952.3	89.5	12.7
2	67	Avocado	*Persea americana*	Laur	1216.4	14208.2	1646.5	928.9	9219.7	4.2	508.5	1258.0	35.3	18.7	615.8	6081.7	49.2	6.9
2	68	Tanuro	*Trichilia monadelpha*	Meli	1125.7	10890.0	1782.5	651.5	4942.2	3.3	323.9	1289.2	40.0	20.3	793.2	6114.0	24.8	4.7
2	69	Okro	*Albizia zygia*	Mimo	726.2	10741.1	1375.9	1046.1	2748.8	3.0	435.3	990.6	52.6	21.0	1066.6	6076.1	14.9	17.6
2	70	Odwono	*Baphia nitida*	Papi	978.3	25035.9	3024.3	1072.8	6997.2	16.9	318.6	2773.7	466.6	29.1	2258.2	5495.8	33.1	23.8
2	71	Konkroma	*Morinda lucida*	Rubi	618.7	18566.8	1677.1	850.2	21643.4	1.2	222.2	2590.3	66.4	28.9	987.0	17798.8	153.5	10.0
2	72	Nyankyerene	*Ficus capensis*	Mora	774.6	21184.2	1643.8	1523.3	27233.9	4.5	592.6	2164.2	76.2	32.3	695.6	32792.1	210.8	33.5
2	73	Doma	*Ficus leprieuri*	Mora	893.2	13757.5	1815.7	834.5	12365.2	1.2	298.5	2519.6	125.3	27.0	774.4	6352.2	52.5	9.5
2	74	Funtum	*Funtumia elastica*	Apoc	786.8	13347.9	1933.2	892.9	14210.5	1.5	389.1	2608.7	46.2	34.4	593.9	20092.4	141.7	3.8
2	76	Dubrafo	*Mareya micrantha*	Euph	723.5	20412.8	2213.6	1177.6	8968.1	7.0	377.0	2785.5	388.7	33.0	1545.4	6413.0	52.0	23.0
2	77	Konkroma	*Morinda lucida*	Rubi	792.7	9256.8	1537.3	1176.7	23672.5	4.0	560.9	1308.0	54.2	23.1	646.3	10437.8	117.5	59.5
2	78	Tanuro	*Trichilia monadelpha*	Meli	1748.7	13683.0	2074.6	403.1	2885.1	9.9	231.3	1142.8	115.0	16.1	1244.1	5828.8	15.1	13.2
2	79	Okro	*Albizia zygia*	Mimo	1010.8	9618.6	2052.3	1092.3	13835.8	18.1	515.0	2153.1	303.2	49.7	1419.0	7623.2	89.4	27.8
1	86	Kyenkyen	*Antiaris toxicaria*	Mora	598.9	6927.4	1235.3	249.9	4842.3	0.0	122.6	1349.8	94.1	2.5	473.4	3452.7	22.7	3.5
1	87	Okro	*Albizia zygia*	Mimo	579.9	16713.7	1290.6	379.0	4132.8	0.0	202.9	5275.3	69.3	66.8	461.9	8607.2	27.8	5.7

1	88	Awiemfosamina	*Albizia ferruginea*	Mimo	659.7	8183.9	1363.6	696.6	17837.0	0.0	201.3	3500.6	26.0	29.3	832.5	14594.6	124.0	9.3
1	89	Nyankyerene	*Ficus capensis*	Mora	866.6	6564.9	2217.0	489.2	3704.1	0.0	302.1	1542.7	82.5	17.4	966.6	7406.1	18.5	11.5
1	90	Okro	*Albizia zygia*	Mimo	902.2	12125.2	1572.0	833.8	11036.0	0.0	381.8	1855.3	53.2	22.7	518.6	7740.6	64.1	6.7
1	91	Tanuro	*Trichilia monadelpha*	Meli	936.3	16231.3	2192.5	1376.4	14825.4	1.9	686.8	2521.5	106.2	41.7	648.8	10425.2	105.7	38.2
1	92	Akyebire	*Blighia unijugata*	Sapin	731.9	10826.2	3974.3	1342.4	22236.8	0.0	483.6	3385.4	667.3	27.7	382.3	8105.7	111.3	6.6
1	93	Duabire	*Greenwayodendron oliveri*	Anno	1118.5	11752.8	1214.8	583.6	7457.5	6.6	174.8	4070.6	23.3	37.6	1660.9	6557.2	68.3	13.1
1	94	Akata	*Bombax buonopozense*	Bomb	992.7	11672.1	2473.5	1693.1	11213.7	5.9	518.1	3157.3	812.4	102.6	1050.1	6854.1	70.2	21.2
1	95	Konkroma	*Morinda lucida*	Rubi	793.7	19152.0	1688.3	428.8	3926.2	10.3	301.1	1528.0	76.6	2183.1	5609.3	14.9	28.0	28.0
1	96	Gyama	*Alchornea cordifolia*	Euph	1301.3	29137.6	2040.6	990.6	15569.3	4.1	368.7	2420.1	51.3	39.7	818.3	19093.3	153.5	3.3
1	97	Dubrafo	*Mareya micrantha*	Euph	947.8	10316.4	2790.4	935.2	16907.7	2.6	308.3	1396.8	67.3	22.7	507.0	24540.3	190.5	21.0
1	98	Dubrafo	*Mareya micrantha*	Euph	855.2	15534.4	2131.8	1203.5	18038.5	15.0	708.8	2787.2	39.9	40.9	699.5	17202.5	164.5	9.7
1	99	Dubrafo	*Mareya micrantha*	Euph	810.8	24860.4	1467.9	660.9	3888.2	8.2	394.5	2743.5	171.3	34.9	901.0	8358.6	13.3	7.1
1	100	Ansedodowa	*Cola millenii*	Sterc	1256.6	18401.9	2973.9	2480.7	16221.7	7.3	694.2	4003.2	1290.6	52.2	948.0	7940.0	87.6	23.5
1	101	Konkroma	*Morinda lucida*	Rubi	888.4	19972.2	1661.5	648.4	14564.0	3.5	313.0	4309.3	86.1	116.9	968.8	10459.3	145.2	12.2
1	102	Odum	*Milicia excelsa*	Mora	683.6	22273.1	1270.8	447.2	10978.9	6.7	174.9	2200.1	49.0	28.6	785.9	7702.5	85.5	7.9
1	103	Domini	*Ficus capensis*	Mora	1280.0	15045.0	3386.8	1100.8	20560.6	10.2	304.8	5803.2	78.8	63.6	1278.4	8544.0	195.0	25.1
1	104	Doma	*Ficus leprieuri*	Mora	650.2	24308.6	2200.4	384.3	5253.8	8.3	148.3	1771.1	191.8	41.5	963.4	5255.1	23.6	8.8
1	105	Okro	*Albizia zygia*	Mimo	635.0	7273.2	1471.1	1050.8	22534.7	4.7	266.6	950.1	59.7	18.5	490.9	13066.1	163.9	4.0
1	106	Tanuro	*Trichilia monadelpha*	Meli	759.9	19.1	2118.6	382.3	6931.6	5.7	151.3	1673.3	218.7	39.4	914.1	5407.7	41.9	6.7
1	107	Okro	*Albizia zygia*	Mimo	711.6	8565.2	2370.1	1561.3	27531.4	6.0	678.7	3557.5	57.2	46.9	727.6	27863.6	266.7	7.6
1	108	Dubrafo	*Mareya micrantha*	Euph	662.8	2431.7	2031.2	678.6	5578.2	5.1	253.4	1730.0	123.8	28.4	862.9	5968.1	27.0	7.1
1	109	Okro	*Albizia zygia*	Mimo	703.4	1655.7	1598.2	272.2	178.4	7.1	207.2	1283.3	77.5	28.0	596.3	4400.2	20.9	9.0
1	110	Okro	*Albizia zygia*	Mimo	818.7	14667.2	4283.9	686.5	10200.9	16.5	285.6	5454.1	355.6	86.7	4748.6	7019.1	71.8	81.6
1	111	Framo	*Terminalia superba*	Comb	771.9	18694.5	2204.6	630.0	4374.8	13.6	443.7	2068.0	49.1	35.1	1754.1	6118.4	22.2	40.1
2	113	Nseduansehoma	*Castonala paradoxa*	Conn	1977.4	20508.6	2157.6	573.4	5759.0	39.2	393.9	2523.8	97.0	46.8	2121.2	7482.5	28.0	467.9
1	115	Nseduansehoma	*Castonala paradoxa*	Conn	877.8	10303.1	1750.5	1297.4	29295.2	5.1	311.7	1411.8	69.3	32.5	498.1	30562.8	304.9	9.1
1	116	Doma	*Ficus leprieuri*	Mora	1360.9	14348.0	2071.1	1666.6	35810.9	9.0	500.8	3493.1	116.7	58.6	745.8	34681.2	341.3	18.1
1	117	Konkroma	*Morinda lucida*	Rubi	629.3	10947.8	2060.1	1281.1	19727.0	8.2	226.6	3918.1	609.2	46.0	1013.2	5582.5	157.4	52.4
1	118	Konkroma	*Morinda lucida*	Rubi	739.5	13092.5	2056.0	1420.8	19003.9	6.3	298.8	3423.1	580.7	55.6	991.9	6902.2	155.2	35.2
1	120	Dubrafo	*Mareya micrantha*	Euph	775.7	28249.2	3107.0	1067.9	15899.4	15.7	415.7	4522.3	53.7	68.2	2597.9	12319.4	151.3	13.1
1	121	Doma	*Ficus leprieuri*	Mora	678.7	27491.1	2701.1	1091.2	20438.6	9.7	350.9	4404.8	87.2	49.6	1079.6	10128.6	188.5	18.3
1	122	Doma	*Ficus leprieuri*	Mora	802.4	21253.4	1875.2	1362.9	14665.7	1.8	414.3	3669.9	62.8	30.1	953.5	6772.1	138.2	12.4
1	123	Dubrafo	*Mareya micrantha*	Euph	624.6	10911.3	2184.1	1191.3	25937.0	0.0	342.9	1755.3	59.6	14.6	468.9	15325.2	266.7	0.0
1	125	Domini	*Ficus capensis*	Mora	711.6	32921.9	2576.9	1313.4	12308.4	5.9	433.4	3549.9	49.2	28.6	2146.6	7377.7	108.3	29.6

Inventory and total element concentrations (mg kg^{-1}) of barks of tree species in Dopiri secondary Forest.

Plot No.	Tree No.	Local Name	Scientific Name	Family Name	Elements (mg kg^{-1}) Na	K	S	Al	Ca	Cu	Fe	Mg	Mn	Mo	P	Si	Sr	Zn
3	1	Pepea	*Magaritaria discoidea*	Euph	708.1	12345.1	1575.3	1315.4	30107.2	37.5	177.5	710.2	127.4	24.9	652.8	4549.5	132.3	14.8
3	2	Tanuro	*Trichilia monadelpha*	Meli	954.9	8446.0	1955.1	1594.2	46209.3	22.2	167.4	1591.0	57.1	37.1	666.8	6479.5	176.3	16.2
3	3	Pepea	*Magaritaria discoidea*	Euph	502.7	7400.1	1718.5	759.0	19660.5	20.9	97.8	1250.6	84.1	38.7	381.5	3171.6	95.1	21.2
3	4	Okro	*Albizia zygia*	Mimo	408.9	5163.8	2862.0	1217.3	24635.8	22.2	208.3	732.1	113.7	30.4	375.8	2367.4	150.9	22.0
3	5	Tanuro	*Trichilia monadelpha*	Meli	667.7	7797.0	2948.0	1956.9	73241.5	26.1	105.9	1474.5	39.8	48.8	523.6	3271.2	185.5	16.0
3	6	Wawa	*Triplochiton scleroxylon*	Sterc	895.5	13959.7	3108.7	916.2	24711.1	22.6	103.7	914.5	37.8	38.8	347.0	4323.9	130.1	8.5
3	7	Funtum	*Funtumia elastica*	Apoc	749.2	3986.5	1242.4	945.1	22840.1	23.5	147.0	705.5	58.8	39.8	328.4	4115.9	151.9	13.6
3	8	Doma	*Ficus leprieuri*	Mora	1290.1	14385.8	1954.6	1878.5	53456.2	28.1	150.8	1443.7	45.1	64.2	597.2	7144.3	519.7	20.3
3	9	Doma	*Ficus leprieuri*	Mora	1372.0	7799.7	1235.5	1439.8	40839.5	27.1	152.4	547.0	36.1	50.3	374.7	8895.6	335.4	11.9
3	10	Tanuro	*Trichilia monadelpha*	Meli	731.9	5773.0	2277.2	1435.6	51181.1	21.1	125.3	1459.5	38.5	44.7	490.9	3270.6	170.6	17.5
3	11	Tanuro	*Trichilia monadelpha*	Meli	721.2	3194.8	1848.2	1388.3	49501.6	24.1	186.6	1777.4	41.2	58.6	490.6	2448.5	147.2	18.3
3	12	Doma	*Ficus leprieuri*	Mora	1143.3	22592.4	2494.1	1801.5	63390.5	32.2	134.8	804.5	47.5	56.5	724.8	5588.3	462.3	40.1
3	13	Okro	*Albizia zygia*	Mimo	1057.1	7228.3	1288.6	896.3	20368.5	36.9	140.1	545.6	54.5	61.6	473.2	3959.9	128.6	22.8
3	16	Odwono	*Baphia nitida*	Papi	387.9	8986.8	1189.6	831.3	19641.8	21.9	136.8	950.0	195.4	36.3	424.1	3925.4	101.7	9.0
3	17	Odwono	*Baphia nitida*	Papi	492.1	8963.8	948.2	710.1	14805.3	17.2	3530.8	707.3	71.5	31.5	367.8	4907.9	68.9	15.1
3	18	Gyama	*Alchornea cordifolia*	Euph	361.3	2914.8	1555.6	1398.3	39010.7	22.7	178.2	1041.7	48.7	39.2	300.6	3065.6	109.2	13.6
3	19	Tanuro	*Trichilia monadelpha*	Meli	484.7	4234.2	2020.0	1972.1	68499.5	24.6	140.1	1963.0	36.1	56.5	416.9	3630.5	147.8	11.7
3	22	Sese	*Holarrhena floribunda*	Apoc	462.4	5784.6	889.4	870.2	28512.1	6.5	98.5	664.1	89.8	0.8	331.3	1961.0	175.2	5.9
3	24	Okro	*Albizia zygia*	Mimo	750.1	5540.8	2026.0	785.3	18841.7	10.5	144.7	371.8	126.2	0.0	451.7	4885.8	125.8	31.4
3	27	Dubrafo	*Mareya micrantha*	Euph	467.3	8409.6	2374.4	1183.6	48287.8	7.8	78.6	2107.3	27.3	17.6	345.2	2601.5	253.6	4.9
3	31	Sinuro	*Alstonia boonei*	Apoc	278.0	4045.9	475.0	613.8	12770.1	10.8	166.9	921.6	33.1	10.6	314.6	2543.5	92.1	7.4
3	33	Yaya	*Amphimas pterocarpoides*	Caes	716.6	4704.1	1955.5	937.0	7638.1	15.1	131.6	1554.6	32.5	30.3	355.4	2509.6	229.2	16.5
3	35	Opamfufuo	*Macaranga hurifolia*	Euph	459.5	9780.5	210.6	477.6	9489.7	8.0	81.3	678.5	23.6	11.1	209.4	4038.0	67.0	5.2
3	36	Odwono	*Baphia nitida*	Papi	637.5	8331.1	3840.6	902.5	27606.5	11.5	117.5	2097.9	121.4	24.2	765.9	2216.0	164.1	14.2
3	37	Sesemasa	*Newbouldia laevis*	Bign	642.7	7467.7	706.8	1060.5	27946.0	11.7	207.3	917.8	34.9	13.7	298.1	4299.5	154.5	8.2
3	38	Odwono	*Baphia nitida*	Papi	408.6	7892.8	2308.2	921.0	26810.5	16.8	138.3	1012.9	89.3	19.7	474.9	2950.0	97.7	14.6
3	39	Tanuro	*Trichilia monadelpha*	Meli	477.9	5394.9	2764.8	1713.5	63222.3	13.7	112.0	1618.0	52.1	38.6	450.6	2757.5	163.7	10.9
2	40	Nyankyerene	*Ficus capensis*	Mora	495.8	7187.3	1908.2	1893.2	68558.4	17.8	152.5	2113.7	62.7	46.3	421.2	8503.2	584.6	2.7
2	41	Sinuro	*Alstonia boonei*	Apoc	935.3	14265.6	1002.6	1250.6	33619.5	21.6	155.3	2140.8	60.2	49.2	478.6	6523.7	191.1	12.1
2	42	Konkroma	*Morinda lucida*	Rubi	459.7	21942.3	2059.6	3334.7	6990.2	18.4	150.6	1276.5	144.5	42.2	479.6	3188.6	33.5	8.6
2	43	Tanuro	*Trichilia monadelpha*	Meli	673.5	4412.1	1755.6	1578.1	49381.8	19.5	207.7	1012.6	74.4	39.6	428.8	5863.3	150.3	9.3

2	44	Odwono	*Baphia nitida*	Papi	453.0	5108.0	1942.5	474.8	12315.1	14.3	138.0	875.0	155.6	28.3	762.7	2312.5	55.0	32.9
2	45	Okro	*Albizia zygia*	Mimo	422.6	5459.5	2018.3	659.5	19837.9	15.2	100.4	164.6	73.8	26.8	409.3	2268.1	108.9	15.2
2	46	Gyama	*Alchornea cordifolia*	Euph	425.6	6689.9	1294.8	689.0	16843.2	21.7	153.9	1595.6	77.1	45.5	480.1	3963.9	56.2	12.6
2	47	Nseduansehoma	*Castonala paradoxa*	Conn	380.4	3811.6	1647.9	1094.5	33801.2	18.1	165.5	1577.3	88.1	44.8	449.0	4442.6	313.6	7.4
2	49	Odwonkobire	*Baphia pubescens*	Papi	225.7	6079.2	1891.7	706.0	5894.2	16.5	119.2	1047.6	92.8	33.3	323.4	2337.8	122.1	5.9
2	50	Konkroma	*Morinda lucida*	Rubi	539.0	10943.9	2115.2	2379.9	7317.3	17.6	516.3	602.2	203.0	31.1	359.7	3573.7	34.3	15.3
2	51	Okro	*Albizia zygia*	Mimo	364.4	5700.9	2828.0	971.4	32263.7	13.9	134.8	376.5	88.5	20.2	425.0	2288.2	1794.9	14.4
2	52	Okro	*Albizia zygia*	Mimo	278.2	9990.6	3345.8	689.2	19327.1	10.6	127.5	1042.8	51.2	20.0	366.2	2181.6	170.7	6.6
2	53	Doma	*Ficus leprieuri*	Mora	777.2	15581.8	3338.4	1307.5	40347.8	12.4	145.5	1535.7	53.6	28.7	370.6	7642.7	398.6	19.5
2	54	Gyama	*Alchornea cordifolia*	Euph	695.1	5519.1	2464.2	1058.5	30596.9	18.8	115.4	1750.3	68.7	29.2	400.0	5194.7	89.2	35.7
2	55	Konkroma	*Morinda lucida*	Rubi	520.9	13062.8	1537.1	3215.1	12903.7	14.5	205.7	976.0	432.6	29.8	324.2	4099.3	101.2	11.0
2	56	Konkroma	*Morinda lucida*	Rubi	737.4	11059.2	666.8	1201.8	27405.8	16.8	191.5	7503.4	218.8	85.5	385.3	5680.6	148.3	2.0
2	57	Doma	*Ficus leprieuri*	Mora	611.3	11429.5	2898.9	1804.9	56578.9	16.6	300.3	2246.2	82.7	69.0	362.3	11676.2	527.2	23.0
2	58	Okro	*Albizia zygia*	Mimo	591.3	6290.5	3341.2	796.9	19844.7	13.0	96.6	3011.0	47.8	45.5	477.4	4247.7	246.8	3.7
2	60	Okro	*Albizia zygia*	Mimo	386.8	4677.4	1985.0	798.7	24803.6	15.8	169.7	465.6	98.3	22.6	390.5	2419.8	191.6	16.3
2	61	Gyama	*Alchornea cordifolia*	Euph	362.5	6157.9	1191.6	423.8	8643.7	13.6	124.4	778.3	56.3	25.8	1241.7	2582.0	2689.5	10.0
2	62	Kyenkyen	*Antiaris toxicaria*	Mora	289.1	16783.3	1265.7	827.3	23524.5	15.7	129.2	1232.5	65.1	35.7	547.7	7465.6	237.0	10.0
2	63	Kyereye	*Pterygota macrocarpa*	Sterc	312.1	9989.2	772.1	1054.7	34099.2	15.8	113.4	5555.6	82.6	78.3	601.2	2473.0	165.7	4.8
2	65	Domini	*Ficus capensis*	Mora	835.8	15989.8	2969.5	1286.3	37215.8	16.2	124.0	1353.2	63.7	37.8	743.0	6985.5	311.9	17.5
2	66	Avocado	*Persea americana*	Laur	361.0	9246.5	1439.4	514.3	9970.7	12.8	90.4	890.2	58.7	29.4	296.9	3329.6	80.9	24.1
2	67	Avocado	*Persea americana*	Laur	349.6	8138.8	1225.6	426.5	8791.7	22.3	147.6	744.1	57.8	40.4	340.3	2186.1	72.1	20.7
2	68	Tanuro	*Trichilia monadelpha*	Meli	650.4	4866.9	2770.1	1763.3	63215.4	16.8	97.2	1719.2	48.1	75.0	399.8	2845.6	161.2	2.3
2	69	Okro	*Albizia zygia*	Mimo	323.2	5941.8	2036.6	80.8	23557.7	14.7	134.9	488.2	67.7	36.4	450.3	1571.7	160.7	17.5
2	70	Odwono	*Baphia nitida*	Papi	372.9	10303.8	1759.4	469.0	9975.2	19.4	139.1	920.9	95.7	39.0	765.1	2709.3	48.0	13.0
2	71	Konkroma	*Morinda lucida*	Rubi	409.3	9438.8	2062.5	1404.7	4995.5	18.0	95.7	795.4	165.6	31.8	444.8	3800.0	25.0	9.5
2	72	Nyankyerene	*Ficus capensis*	Mora	416.1	11085.7	3303.7	692.2	17711.9	15.2	138.7	1941.8	54.0	39.1	364.3	3725.8	189.7	2.4
2	73	Doma	*Ficus leprieuri*	Mora	1006.5	21633.8	4334.9	2158.0	73762.9	19.4	164.1	2297.2	212.0	52.9	477.5	7575.6	621.6	52.1
2	74	Funtum	*Funtumia elastica*	Apoc	443.2	6924.0	2210.6	1026.8	27715.9	20.1	167.8	1086.4	89.0	44.5	413.8	3239.9	154.5	9.9
2	76	Dubrafo	*Mareya micrantha*	Euph	560.4	8142.7	3045.8	1328.4	39230.0	17.2	127.1	2038.4	51.0	47.4	372.1	5278.2	265.1	1.3
2	77	Konkroma	*Morinda lucida*	Rubi	1131.0	31781.7	4748.6	4427.9	21758.7	19.1	229.2	1913.1	191.6	46.3	809.4	6341.6	112.5	16.9
2	78	Tanuro	*Trichilia monadelpha*	Meli	411.2	4441.5	2497.5	1728.6	55396.5	15.7	130.5	1630.8	82.2	45.4	422.5	3236.2	161.1	6.2
2	79	Okro	*Albizia zygia*	Mimo	285.1	5373.6	2341.3	1068.3	28633.3	16.2	178.3	583.1	104.9	25.8	381.4	2441.6	160.6	19.6
1	86	Kyenkyen	*Antiaris toxicaria*	Mora	586.1	6517.9	2017.3	606.2	15440.3	21.8	214.6	1580.3	78.7	39.5	636.4	12962.4	130.8	31.0
1	87	Okro	*Albizia zygia*	Mimo	332.1	3851.5	2482.6	791.1	23265.4	17.3	124.5	207.1	106.3	26.9	311.1	3336.8	118.1	17.4

1	88	Awiemfosamina	*Albizia ferruginea*	Mimo	468.6	7710.5	1596.9	611.8	13875.3	21.4	120.0	3455.5	73.8	55.5	289.9	4390.5	113.9	3.9
1	89	Nyankyerene	*Ficus capensis*	Mora	283.1	10905.2	1425.0	1227.1	43723.8	12.5	101.6	540.4	58.1	28.8	292.2	8445.6	346.8	2.7
1	90	Okro	*Albizia zygia*	Mimo	560.2	3076.9	3024.7	912.2	26796.5	21.7	122.7	540.0	128.9	31.8	346.7	3536.7	193.4	5.7
1	91	Tanuro	*Trichilia monadelpha*	Meli	329.3	8076.3	2281.8	1087.9	35622.7	18.1	134.9	1493.1	90.2	43.7	451.9	2850.4	119.5	10.3
1	92	Akyebire	*Blighia unijugata*	Sapin	237.6	2932.5	4843.8	1140.8	37939.0	15.8	148.1	2169.6	69.3	47.2	332.1	2349.2	287.5	60.3
1	93	Duabire	*Greenwayodendron oliveri*	Anno	197.2	4154.2	3004.6	889.8	24093.0	19.2	147.0	1094.8	196.7	33.1	309.4	2036.6	133.0	2.5
1	94	Akata	*Bombax buonopozense*	Bomb	511.3	3561.7	431.1	676.9	18188.0	20.2	181.4	4509.4	79.5	91.9	307.0	172.3	158.9	15.2
1	95	Konkroma	*Morinda lucida*	Rubi	302.2	35926.0	5426.1	6364.2	23083.6	21.3	78.1	682.0	274.5	50.0	680.2	3028.0	120.6	19.8
1	96	Gyama	*Alchornea cordifolia*	Euph	327.9	5335.2	2162.8	1114.0	38663.9	11.9	98.6	1085.2	74.9	27.6	225.5	2584.8	852.7	8.2
1	97	Dubrafo	*Mareya micrantha*	Euph	383.9	9930.7	2690.5	884.6	25436.8	15.3	141.0	2371.7	72.3	41.3	348.3	5527.1	194.7	0.9
1	98	Dubrafo	*Mareya micrantha*	Euph	425.2	13436.8	2934.6	617.7	16243.9	15.5	158.0	1796.4	67.9	30.7	300.5	3787.0	172.0	1.3
1	99	Dubrafo	*Mareya micrantha*	Euph	753.8	15566.3	2942.2	1377.2	33072.8	20.2	353.8	3186.6	92.9	51.0	449.3	6806.0	303.2	4.3
1	100	Anansedodowa	*Cola millenii*	Sterc	652.1	11087.8	1472.0	3024.8	7516.2	17.9	500.1	593.1	150.3	31.5	824.6	3838.3	45.9	12.5
1	101	Konkroma	*Morinda lucida*	Rubi	517.4	26423.8	4129.1	6073.8	9941.2	14.8	250.8	726.9	220.9	38.8	405.4	2420.6	387.7	16.8
1	102	Odum	*Milicia excelsa*	Mora	502.2	7432.0	1306.9	964.1	1982.8	15.1	142.6	1426.6	103.4	33.9	352.4	4573.1	288.9	0.5
1	103	Domini	*Ficus capensis*	Mora	280.2	6354.3	1439.1	750.4	22733.5	16.1	106.2	551.4	66.2	25.6	281.2	3517.6	193.8	13.3
1	104	Doma	*Ficus leprieuri*	Mora	356.9	14448.2	1308.7	924.9	28841.8	17.1	161.2	1108.6	74.9	37.7	421.3	9893.6	279.3	29.8
1	105	Okro	*Albizia zygia*	Mimo	355.6	4730.4	2419.2	908.0	27130.6	16.0	165.5	537.1	132.1	38.6	340.0	2621.7	186.8	22.0
1	106	Tanuro	*Trichilia monadelpha*	Meli	345.8	7049.0	1977.1	1376.4	48883.5	13.0	102.2	821.1	65.3	25.6	407.7	2633.4	162.0	7.3
1	107	Okro	*Albizia zygia*	Mimo	387.5	6916.0	2896.6	989.6	31194.5	15.9	137.6	183.2	119.5	38.7	389.4	2551.6	213.2	16.9
1	108	Dubrafo	*Mareya micrantha*	Euph	362.8	7485.2	3819.0	1668.8	49861.5	18.7	162.2	2585.6	87.5	52.3	100.5	5191.7	428.5	3.0
1	109	Okro	*Albizia zygia*	Mimo	498.6	5301.0	2471.6	643.7	12543.9	12.7	111.5	426.2	82.9	18.8	62.6	4376.2	99.5	8.0
1	110	Okro	*Albizia zygia*	Mimo	318.1	4767.3	1915.2	700.4	20386.0	18.9	138.5	627.3	114.0	26.5	372.0	437.8	153.4	12.3
1	111	Framo	*Terminalia superba*	Comb	529.3	16960.2	1385.5	979.0	26714.1	20.0	161.6	1312.0	209.4	35.2	318.1	4909.6	180.7	34.4
2	113	Nseduansehoma	*Castonala paradoxa*	Conn	385.7	10586.8	2416.0	853.1	25025.2	14.1	163.7	1119.6	107.5	27.9	577.7	4032.1	211.2	13.8
1	115	Nseduansehoma	*Castonala paradoxa*	Conn	858.6	11799.8	1831.2	1105.8	30892.3	19.8	201.3	600.7	113.9	36.0	520.6	5511.6	282.1	10.1
1	116	Doma	*Ficus leprieuri*	Mora	632.0	14603.4	3911.2	1396.9	45169.5	22.4	143.3	1597.7	88.2	57.6	352.8	23001.6	444.5	16.4
1	117	Konkroma	*Morinda lucida*	Rubi	403.9	13197.4	2283.7	2829.1	8330.9	17.1	130.2	87.1	164.8	39.1	384.6	3068.5	59.6	10.6
1	118	Konkroma	*Morinda lucida*	Rubi	373.7	21062.8	1738.0	1495.5	50832.7	18.4	137.1	665.8	69.7	42.6	410.3	13954.5	398.7	7.3
1	120	Dubrafo	*Mareya micrantha*	Euph	478.8	14638.9	4171.6	1355.4	43882.1	19.2	155.3	2561.5	69.6	57.6	355.1	8200.2	301.8	3.6
1	121	Doma	*Ficus leprieuri*	Mora	713.9	15811.0	3332.3	1689.3	57228.8	24.3	156.8	1171.7	120.3	48.1	349.4	11093.4	522.2	39.7
1	122	Doma	*Ficus leprieuri*	Mora	446.4	15924.5	1925.0	1411.9	46598.3	18.3	110.5	1357.4	98.8	45.9	348.1	6466.7	412.5	15.8
1	123	Dubrafo	*Mareya micrantha*	Euph	611.8	11733.9	3760.5	1192.7	35338.8	15.7	114.4	1415.1	55.0	39.2	321.3	6728.5	299.0	2.0
1	125	Domini	*Ficus capensis*	Mora	352.2	21881.2	3995.7	1075.0	36451.0	11.7	110.8	126.2	81.1	21.7	422.2	5022.2	328.5	18.3