Distribution Characteristics of Mineral Elements in Tree Species from Two Contrasting Secondary Forests in Ghana

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Abstract

Tree species in two contrasting forests were evaluated on three plots of 0-19 ha (0.57 ha) in each secondary forest. Tree species populations were 44 in Akyaakrom (AS), 29 in Dopiri (DS), and families were 18 in AS and 16 in DS. Tree densities were 121 and 99 in AS and DS, respectively, in 0.57 ha. In terms of tree species population, diversity and density, AS was superior to DS. 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 both forests were about three times higher than they were in the leaves. Soil nutrients showed that Ca, Mg and N concentrations were higher in the DS than in AS within 0-60 cm soil depths. However, at 30-45 cm depth, Ca, Mg, K and N concentrations were higher in AS than in DS. The nutrient element concentrations were high at 0-15 cm than further down the soil depths for the two forests. The land quality indexes of the principal nutrients N, P, K, Ca and Mg were higher in AS than in DS. Thus, eight tree families in AS and five in DS, and tree species numbers 23 and 12 were peculiar to each site. This may suggest the higher tree population and diversity recorded for AS than for DS.

Introduction

It is the general trend that fertile primary forest lands are preferred for agriculture. The shifting cultivation agriculture involving slash and burn method in Ghana destroys the primary fertile lands. Such extensive wonton destruction of the forest environment required rapid interventions to salvage and conserve the forest ecosystems. Hence, about a third of Ghana's land area has been designated as forest and nature reserves by the Government and the non-reserved areas are intensively farmed. Farms are abandoned after a period of 2–3 years of continuous cropping in search for new fertile lands. Because of the pressure on the land for farming due to population growth and scarcity of arable lands, there has been rapid total conversion of primary forest into scrub, farm-bush and secondary forests (Longman & Jenik, 1987). As a result, there are more secondary than primary forests in most tropical countries (Gomez-Pompa & Vazquez-Yanes, 1974).

The major factor for the structure of the forest tree communities is the distribution characteristics of mineral elements in both trees and soils (Walter, 1995). Tree species require specific mineral elements in specific quantities for growth, reproduction and survival in an ecosystem. The ratio of plant and soil nutrient status indicates the land quality index for each secondary forest. The nutrition and nutrient constituent in the tree species will offer guidelines for prescription of potential agroforestry intervention strategies and the land quality index will indicate which of the secondary forests would support plant growth. The objective of this study was to determine the mineral element compositions in the leaves and bark of live tree species of two contrasting secondary forests in relation to their soil environments, and to establish whether or not the soil nutrients influence the diversity of the plant communities of the two secondary forests.

Materials and methods

Two secondary forests, Akyaakrom (28 years old) and Dopiri (27 years old) were selected for the study. They were located on both the same latitudes (6^0 33' N and 7^0 03' N) and longitudes (1^0

55’ and 2º 06’ W). Akyaakrom secondary (AS) forest was 200 m (mean elevation) with mean slope of 5⁰ and covered 30 ha. Dopiri secondary forest (DS) was 300 m (mean elevation), covered 20 ha and the mean slope was 9⁰. Dopiri secondary forest was 4 km from human settlement whilst Akyaakrom was located 11 km away. Human disturbances in Dopiri were, therefore, more intense than Akyaakrom.

The two forests belong to the drier part of the moist semi-deciduous forest type classified by Hall & Swaine (1976) and *Celtis-Triplochiton* Association by Taylor (1960). Firewood gathering, hunting for game and timber harvesting persisted in Dopiri whereas in Akyaakrom, game hunting and timber harvesting were the human activities that existed. The soils in both secondary forests were both classified as Ferric Lixisols but in local classification, they are *Bekwai* and *Nzima* series for Akyaakrom and Dopiri, respectively (ISSS, 1994). Annual precipitation is between 1200 and 1500 mm. The *p*H of both soil series ranged 5–7 (Wakatsuki *et al*., 2001).

Three plots, 0.19 ha each, were established in each of the secondary forests and inventoried for floristic composition. Total enumeration of the tree species greater that 5.0 cm diameter at breast height (dbh) was conducted. Local names of the tree species were recorded during field identification and classified according to the guidelines of Irvine (1961) and Hawthorne (1990).

Leaf, bark and soil sampling and analyses

In order to determine the nutrient status of the various tree species and their possible effect on soil, leaf and bark samples of trees above 5.0 cm dbh were collected on 121 species in Akyaakrom and 99 from Dopiri secondary forests. Fresh leaf samples were easily collected from the trees below 15 m high by bending trees and hand picking the leaves. Leaves of trees above 15 m high and difficult to bend were collected by climbing them. Branches were cut down and leaves were picked form the fallen branches. Bark samples taken at dbh were from all trees whose leaf samples were collected. The collected samples were cleaned, chopped and oven-dried at 60 ⁰C for 72 h for nutrient analyses in the laboratory.

Soils in the two secondary forests were sampled at 0–15 cm, 15–30 cm, 30–45 cm and 45–60 cm depths by using the soil auger. Five samples for each depth were taken at random in each of the three plots of the forests. The soil samples were air-dried and screened through 2-mm sieve. The samples from each plot were bulked into composite samples and analyzed for major nutrient elements. Thus, there were three replicate samples for each depth at each site.

The plant and soil samples were milled separately using a vibrating mixer mill. The concentrations of total K were determined by flame photometry. Total N were determined by dry combustion using Sumigraph N-C 90A Analyzer (Sumitomo Chemical). Available phosphorus in soil was determined by the Bray No. 1 method (Bray & Kurtz, 1945). The total Ca and Mg concentrations in plant and soil samples, and total P in plant samples were determined using an inductively coupled plasma spectrometer (ICPS-2000) after digestion by the wet oxidation (HNO_3) method under pressure (Teflon container placed in the oven at 150 ºC for 4 h).

The data generated were statistically analyzed using SAS/StatView (SAS, 1999). The tree species inventoried from each of the secondary forests were grouped into their families to determine their diversity. Analysis of variance (ANOVA) at $P < 0.05$ was used to determine the significance of the nutrient elements in the leaf and bark samples. The input/output ratio was calculated from the nutrient element concentrations in the sampled plant parts and was assumed to be the potential nutrient supply input whilst the soil was taken as the output from which nutrients are acquired by plant species. Ratios of nutrient elements in the plant and soil from each study site were used to calculate land quality indices for each site and compared.

Results and discussion

Plant diversity

Results from the inventory indicated that tree species of Meliaceae family con-stituting 21% dominated in Akyaakrom secondary forest (AS) followed by Moraceae (12%), Apocynaceae (11.4%), Euphorbiaceae (10.8%), Mimosaceae (9.5%) and others (Sterculiaceae, Ulmaceae, Sapindaceae, Papilionaceae, Myristicaceae, Caesalpiniaceae, Combretaceae, Tiliaceae, Simaroubaceae, Bombaceae, Anacardiaceae, Rutaceae, Rubiaceae, Rhmnaceae and Olacaceae constituted 34.8% (Fig. 1a).

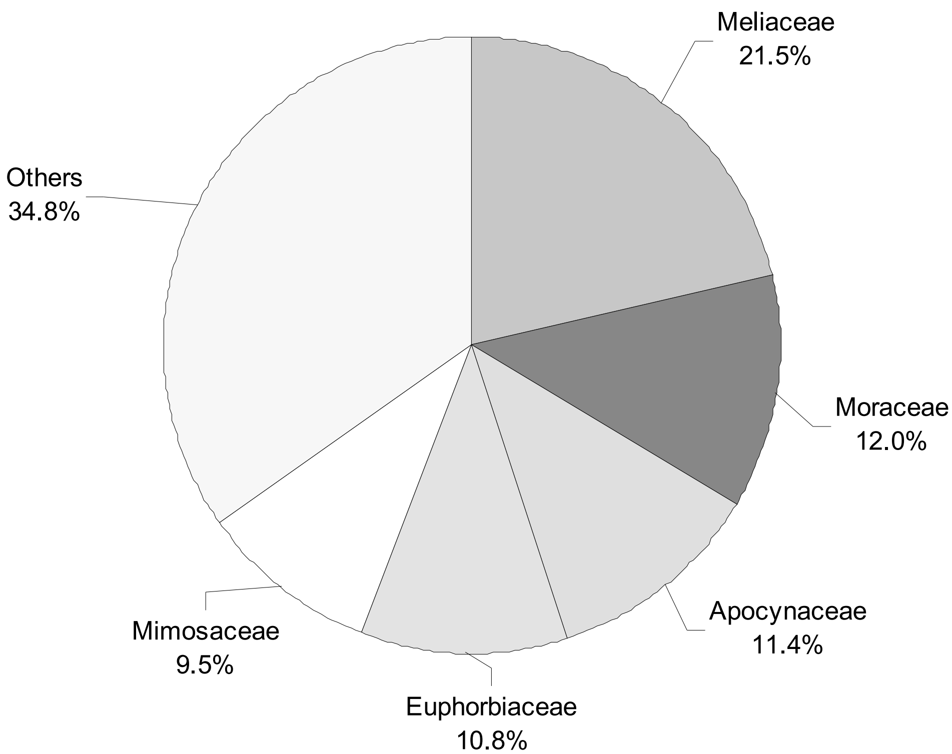

Figure 1a. Percentage (%) composition of plant families in Akyaakrom secondary forest (Area: *0.19 ha* , Tree No. *n* = *158*).

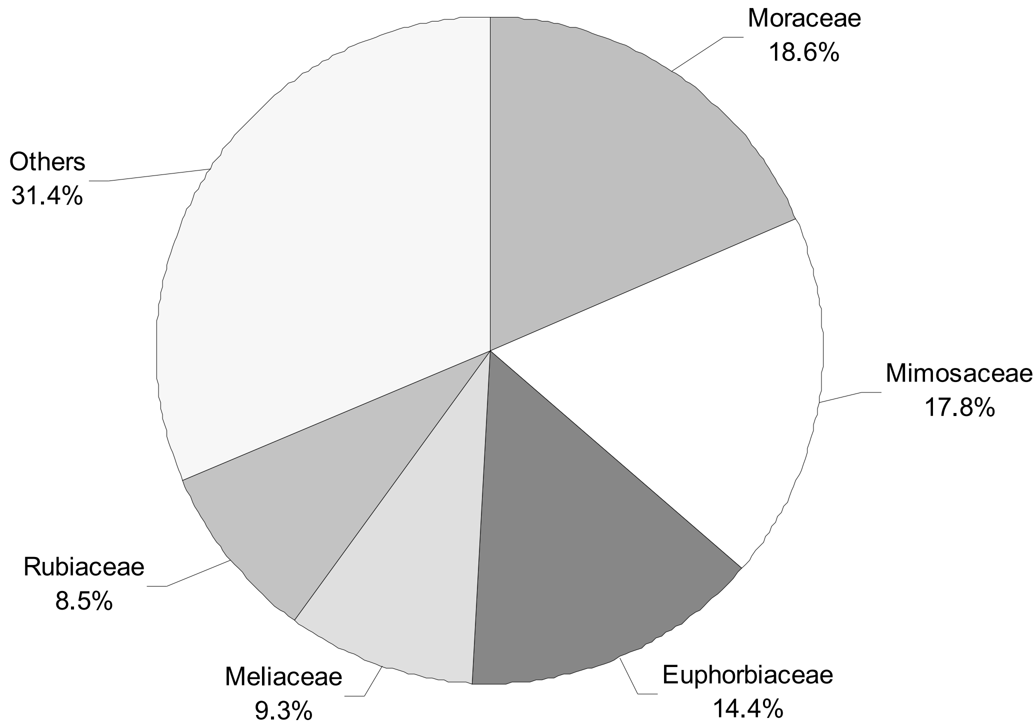

Figure 1b. Percentage (%) composition of plant families in Dopiri secondary forest (Area: *0.19 ha*; Tree No. *n = 118*)

In Dopiri secondary forest (DS), the five 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 Papilionaceae, Apocynaceae, Sterculiaceae, Connaraceae, Sapindaceae, Laurraceae, Combretaceae, Bombaceae, Bignoniaceae, Ulmaceae, Annonaceae and Anacardiaceae, and constituted 34.4% (Fig. 1b). A total of 18 different tree species families were identified in AS and 16 in DS secondary forests. Tree populations were 121 and 99 in the 0.57 ha plots in AS and DS, respectively, and individual tree species were 44 in AS and 29 in DS. Eight tree families recorded in AS and 5 in DS, 23 and 12 tree species numbers inventoried in AS and DS, respectively, did not occur at both sites. Tree density and composition was higher in AS than in DS secondary forests (Fig. 2 and 3).

	Identification				**Element**			
Family name	**Local name**	**Scientific name**	***n***	**N**	**P**	**K**	**Ca**	**Mg**
Anacardiaceae	Kumnini	*Lannea welwitschii*	*2*					
Apocynaceae	Funtum	*Funtumia elastica*	*5*					
“	Kakapenpen	*Rauvolfia vomitoria*	*3*					
“	Sinuro	*Alstonia boonei*	*6*					
Bombaceae	Onyina	*Ceiba pentandra*	*1*					
Caesalpiniaceae	Totro	*Anthonatha macrophylla*	*2*					

“	Yaya	*Amphimas pterocarpoides*	*2*
Euphorbiaceae	Dubrafo	*Mareya micrantha*	*2*
“	Nwama	*Ricinodendron heudelotii*	*1*
“	Pepea	*Magaritaria discoidea*	*10*
Meliaceae	Dubinfufuo	*Lovoa trichilioides*	*1*
“	Dubinkokoo	*Entandrophragma angolense*	*2*
“	Kakadikro	*Trichilia prieuriana*	*1*
“	Mahogany	*Khaya ivorensis*	*1*
“	Tanuro	*Trichilia monadelpha*	*24*
“	Tanuronini	*Trichilia tessmanii*	*1*
Mimosaceae	Awiemfosamina	*Albizia ferruginea*	*1*
“	Okro	*Albizia zygia*	*7*
Moraceae	Doma	*Ficus leprieuri*	*7*
“	Domini	*Ficus capensis*	*1*
“	Kyenkyen	*Antiaris toxicaria*	*1*
“	Nyakomanini	*Myrianthus libericus*	*1*
“	Nyankyerene	*Ficus capensis*	*2*
“	Okure	*Trilepisium madagascariense*	*1*
“	Wonton	*Morus mesozygia*	*1*
Myristicacae	Otie	*Pycnanthus angolensis*	*4*
Olacaceae	Afena	*Strombosia glaucescens*	*1*
Papipilionaceae	Odwonkobire	*Baphia pubescens*	*3*
“	Odwono	*Baphia nitida*	*2*
Rhamnaceae	Ownamdua	*Maesopsis eminii*	*1*
Rutaceae	Oyaa	*Zanthoxylum leprieurii*	*1*
Sapindaceae	Akye	*Blighia sapida*	*1*
Sapindaceae	Akyebire	*Blighia unijugata*	*2*
Simouraceaea	Hotrohotro	*Hannoa klaineana*	*2*
Sterculiaceae	Anansedodowaa	*Cola millenii*	*1*
Sterculiaceae	Cocoa	*Theobroma cacao*	*1*
Sterculiaceae	Danta	*Nesogordonia papaverifera*	*1*
Sterculiaceae	Sofo	*Sterculia tragacantha*	*1*
Sterculiaceae	Wawa	*Triplochiton scleroxylon*	*5*
Sterculiaceae	Wawabema	*Sterculia rhinopetala*	*2*
Tiliaceae	Foto	*Glyphaea brevis*	*1*
Ulmaceae	Esafufuo	*Celtis mildbraedii*	*3*
Ulmaceae	Esakokoo	*Celtis zenkeri*	*2*
Ulmaceae	Nakwa	*Holoptelea grandis*	*1*
	Total no. of tree species		***121***

Key ≤ Mean ≥ Mean ≥ Mean + 2sd

Fig. 2a. Distribution of nutrient elements in leaves of tree species in Akyaakrom secondary forest (AS) *(n = 121)*

	Identification			**Element**				
Family name	**Local name**	**Scientific name**	***n***	**N**	**P**	**K**	**Ca**	**Mg**
Anacardiaceae	Kumnini	*Lannea welwitschii*	*2*					
Apocynaceae	Funtum	*Funtumia elastica*	*5*					
"	Kakapenpen	*Rauvolfia vomitoria*	*3*					
"	Sinuro	*Alstonia boonei*	*6*					
Bombaceae	Onyina	*Ceiba pentandra*	*1*					
Caesalpiniaceae	Totro	*Anthonatha macrophylla*	*2*					
"	Yaya	*Amphimas pterocarpoides*	*2*					
Euphorbiaceae	Dubrafo	*Mareya micrantha*	*2*					
"	Nwama	*Ricinodendron heudelotii*	*1*					
"	Pepea	*Magaritaria discoidea*	*10*					
Meliaceae	Dubinfufuo	*Lovoa trichilioides*	*1*					
"	Dubinkokoo	*Entandrophragma angolense*	*2*					
"	Kakadikro	*Trichilia prieuriana*	*1*					
"	Mahogany	*Khaya ivorensis*	*1*					
"	Tanuro	*Trichilia monadelpha*	*24*					
"	Tanuronini	*Trichilia tessmanii*	*1*					
Mimosaceae	Awiemfosamina	*Albizia ferruginea*	*1*					
"	Okro	*Albizia zygia*	*7*					
Moraceae	Doma	*Ficus leprieuri*	*7*					
"	Domini	*Ficus capensis*	*1*					
"	Kyenkyen	*Antiaris toxicaria*	*1*					
"	Nyakomanini	*Myrianthus libericus*	*1*					
"	Nyankyerene	*Ficus capensis*	*2*					
"	Okure	*Trilepisium madagascariense*	*1*					
"	Wonton	*Morus mesozygia*	*1*					
Myristicacae	Otie	*Pycnanthus angolensis*	*4*					
Olacaceae	Afena	*Strombosia glaucescens*	*1*					
Papipilionaceae	Odwonkobire	*Baphia pubescens*	*3*					
"	Odwono	*Baphia nitida*	*2*					
Rhamnaceae	Ownamdua	*Maesopsis eminii*	*1*					
Rutaceae	Oyaa	*Zanthoxylum leprieurii*	*1*					
Sapindaceae	Akye	*Blighia sapida*	*1*					
"	Akyebire	*Blighia unijugata*	*2*					
Simouraceaea	Hotrohotro	*Hannoa klaineana*	*2*					
Sterculiaceae	Anansedodowaa	*Cola millenii*	*1*					
"	Cocoa	*Theobroma cacao*	*1*					
"	Danta	*Nesogordonia papaverifera*	*1*					
"	Sofo	*Sterculia tragacantha*	*1*					
"	Wawa	*Triplochiton scleroxylon*	*5*					
"	Wawabema	*Sterculia rhinopetala*	*2*					

Tiliaceae	Foto	*Glyphaea brevis*	*1*
Ulmaceae	Esafufuo	*Celtis mildbraedii*	*3*
"	Esakokoo	*Celtis zenkeri*	*2*
"	Nakwa	*Holoptelea grandis*	*1*
	Total no. of tree species		***121***

Key ≤ Mean ≥ Mean ≥ Mean + 2sd

Fig. 2b. Distribution of nutrient elements in bark of tree species in Akyaakrom secondary forest (AS) (*n = 121*)

	Identification					**Element**		
Family name	**Local name**	**Scientific name**	***n***	**N**	**P**	**K**	**Ca**	**Mg**
Anonaceae	Duabire	*Greenwayodendron oliveri*	*1*					
Apocynaceae	Funtum	*Funtumia elastica*	*2*					
"	Sese	*Holarrhena floribunda*	*1*					
"	Sinuro	*Alstonia boonei*	*2*					
Bignoniaceae	Sesemasa	*Newbouldia laevis*	*1*					
Bombaceae	Akata	*Bombax buonopozense*	*1*					
Caesalpiniaceae	Yaya	*Amphimas pterocarpoides*	*1*					
Connaraceae	Nseduansehoma	*castonala paradoxa*	*3*					
Combretaceae	Framo	*Terminalia superba*	*1*					
Euphorbiaceae	Dubrafo	*Mareya micrantha*	*8*					
"	Pepea	*Magaritaria discoidea*	*2*					
	Gyama	*Alchornea cordifolia*	*5*					
	Opamfufuo	*Macaranga hurifolia*	*1*					
Lauraceae	Avocado	*Persia americana*	*2*					
Meliaceae	Tanuro	*Trichilia monadelpha*	*11*					
Mimosaceae	Awiemfosamina	*Albizia ferruginea*	*1*					
"	Okro	*Albizia zygia*	*16*					
Moraceae	Doma	*Ficus leprieuri*	*3*					
"	Domini	*Ficus capensis*	*2*					
"	Kyenkyen	*Antiaris toxicaria*	*3*					
"	Nyankyerene	*Ficus capensis*	*10*					
"	Odum	*Milicia excelsa*	*1*					
Papipilionaceae	Odwonkobire	*Baphia pubescens*	*1*					
"	Odwono	*Baphia nitida*	*6*					
Rubiaceae	Konkroma	*Morinda lucida*	*10*					
Sapindaceae	Akyebire	*Blighia unijugata*	*1*					
Sterculiaceae	Anansedodowaa	*Cola millenii*	*1*					
"	Kyereye	*Pterygota macrocarpa*	*1*					
"	Wawa	*Triplochiton scleroxylon*	*1*					

Total no. of tree species ***99***

Key ≤ Mean ≥ Mean ≥ Mean + 2sd

Fig. 3a. Distribution of nutrient elements in leaves of tree species in Dopiri secondary forest (DS) (*n = 99*)

	Identification			**Element**				
Family name	**Local name**	**Scientific name**	***n***	**N**	**P**	**K**	**Ca**	**Mg**
Anonaceae	Duabire	*Greenwayodendron oliveri*	*1*					
Apocynaceae	Funtum	*Funtumia elastica*	*2*					
“	Sese	*Holarrhena floribunda*	*1*					
“	Sinuro	*Alstonia boonei*	*2*					
Bignoniaceae	Sesemasa	*Newbouldia laevis*	*1*					
Bombaceae	Akata	*Bombax buonopozense*	*1*					
Caesalpiniaceae	Yaya	*Amphimas pterocarpoides*	*1*					
Connaraceae	Nseduansehoma	*castonala paradoxa*	*3*					
Combretaceae	Framo	*Terminalia superba*	*1*					
Euphorbiaceae	Dubrafo	*Mareya micrantha*	*8*					
“	Pepea	*Magaritaria discoidea*	*2*					
	Gyama	*Alchornea cordifolia*	*5*					
	Opamfufuo	*Macaranga hurifolia*	*1*					
Lauraceae	Avocado	*Persia americana*	*2*					
Meliaceae	Tanuro	*Trichilia monadelpha*	*11*					
Mimosaceae	Awiemfosamina	*Albizia ferruginea*	*1*					
“	Okro	*Albizia zygia*	*16*					
Moraceae	Doma	*Ficus leprieuri*	*3*					
“	Domini	*Ficus capensis*	*2*					
“	Kyenkyen	*Antiaris toxicaria*	*3*					
“	Nyankyerene	*Ficus capensis*	*10*					
“	Odum	*Milicia excelsa*	*1*					
Papipilionaceae	Odwonkobire	*Baphia pubescens*	*1*					
“	Odwono	*Baphia nitida*	*6*					
Rubiaceae	Konkroma	*Morinda lucida*	*10*					
Sapindaceae	Akyebire	*Blighia unijugata*	*1*					
Sterculiaceae	Anansedodowaa	*Cola millenii*	*1*					
“	Kyereye	*Pterygota macrocarpa*	*1*					
“	Wawa	*Triplochiton scleroxylon*	*1*					
	Total no. of tree species		***99***					

Key ≤ Mean ≥ Mean ≥ Mean + 2sd

Fig. 3b. Distribution of nutrient elements in bark of tree species in Dopiri secondary forest (DS) (*n = 99*)

Nutrient element composition in live trees of the forests

In Akyaakrom secondary forest (AS), the results of leaf analysis showed total element concentrations in decreasing order of K > Ca > Mg > P > N (Table 1). The mean concentration of K was the highest (14.5 g kg^{-1}) followed by Ca (12.8 g kg^{-1}). The concentrations of Ca, Mg, and P showed high variability in the leaves (69%, 65% and 93%, respectively). The arithmetic means of the element concentrations of the bark samples indicated decreasing order of Ca > K > Mg > P > N. In the bark, Mg variation was high (87%) (Table 1). Tree species leaves from Dopiri secondary forest indicated that the mean concentrations were in the descending order of Ca > K > Mg > P > N (Table 1). The coefficient of variation was highest for Ca (69%) followed by P (63%). Variations in the concentrations of K (47%) and Mg (47%) were medium whilst N was low (28%). The result of the tree bark samples also showed that the element of the tree bark samples decreased in the order Ca > K > Mg > N > P. The coefficients of variation were very high for Mg and K and ranged between 62–79%. Variations in concentrations of N (44%) and Ca (56%) were medium and that for P was relatively small (37%) (Table 1).

TABLE 1

Nutrient element concentrations (g kg^{-1}) in leaves and bark of live tree species in Akyaakrom (AS: N = 121) and Dopiri (DS: n = 99) secondary forests

Site and sample		*Elements concentration (g kg^{-1})*				
		N	*P*	*K*	*Ca*	*Mg*
	Mean	7.20 [b*]	1.17 [a]	14.45 [a]	12.75 [b*]	2.36 [a]
	Sd.	0.18	0.11	8.26	0.83	1.53
AS Leaves	Min.	4.00	0.29	2.65	0.04	0.11
(*n = 121*)	Max.	11.90	8.37	60.33	51.01	8.31
	% C.V**	25.5	93.1	57.2	69.3	64.6
	Mean	3.50 [d]	0.41 [b*]	9.40 [b*]	35.44 [a]	1.68 [b*]
	Sd.	0.09	0.19	5.67	15.63	1.47
AS Bark	Min.	1.80	0.19	1.80	6.71	0.25
(*n = 121*)	Max.	6.30	1.72	26.57	79.63	8.76
	% C.V.	27.2	48.0	60.3	44.1	87.3
	Mean	8.60 [a]	1.23 [a]	14.87 [a]	11.98 [b*]	2.56 [a]
	Sd.	0.24	0.78	7.01	8.31	1.21
DS Leaves	Min.	5.80	0.38	0.02	0.18	0.80
(*n = 99*)	Max.	20.00	5.61	32.92	35.81	6.16
	% C.V.	27.7	63.1	47.2	69.4	47.1
	Mean	5.30 [c]	0.43 [b*]	9.79 [b*]	30.13 [a]	1.36 [b*]
	Sd.	0.24	0.16	6.10	17.01	1.08
DS Bark	Min.	2.00	0.06	2.92	1.98	0.09
(*n = 99*)	Max.	13.70	1.24	35.95	73.76	7.50
	% C.V.	44.0	37.0	62.0	66.0	79.0

* Means of elements with the same letters within a column are not significantly different at $P < 0.05$.

** Percentage coefficient of variation.

Considering the nutrient elements of N, P, K, Ca and Mg in AS live tree species, P was high in the leaves than in the barks (1.2–0.4 g kg^{-1}, respectively) but P distribution in the species leaves varied much more than it did in the bark (93 and 48%, respectively). However, the variabilities of K were 57% and 60% in the leaves and barks, respectively. The Ca concentration in the bark was about three times as it was in the leaves and the variability was low in the bark (44%) as compared to the leaves (69%). Though, Mg concentrations in both leaves and barks showed slight differences, their variations were high except for the leaves of DS. Magnesium concentrations were, however, low for both leaves and bark of the two secondary forests (Table 1). The nutrient elements concentrations, distribu-tions and their variabilities observed in AS tree species were similar to that in the DS.

Between the two study sites, analysis of variance showed that N concentration was significantly higher in the leaves of DS (8.6 g kg^{-1}) than that of AS (7.2 g kg^{-1}) and also barks of DS (5.3 g kg^{-1}) and AS (3.5 g kg^{-1}) ($P < 0.05$). The N concentration in barks of both forests were, however, not significantly different ($P < 0.05$). However, concentra-tions of N, P and K were significantly higher in the leaves than they were in their barks. Conversely, Ca and Mg showed significant higher concentrations in the bark than in the leaves (Table 1). Nitrogen, P and K concentrations were about two times higher in the leaves than in the barks of both secondary forests. Apart from Ca, the other nutrient concentrations in the leaves were generally higher than they were in the barks for the two secondary forests. Generally, concentrations of Ca in tree species bark of both forests were about three times higher than they were in the leaves (Table 1).

Walter (1995) reported that the bark of tree trunks contains relatively large amount of Ca. Annan-Afful *et al*. (2004) also reported that bark samples tended to exhibit lower concentrations of N, P, K and Mg but higher concentration of Ca. The higher concentrations of Ca and Mg recorded in the bark than in the leaves suggested the use of Ca and Mg for the maintenance of the cell wall of the trunk whereas the higher concentrations of N, P and K recorded in the leaves suggested efficient photosyn-thesis. These elements are required in different concentrations and at different parts of the tree species for different functions. The results of the leaf and bark samples analyzed from AS showed that out of 121 samples, more than 64% of the tree species contained lower, and 4% higher concentrations of N, P, K, Ca and Mg than the overall mean (Fig. 2a,b).

For the total of 99 tree species samples analyzed from DS, 58% of tree species contained lower, and 2% contained higher concentrations of N, K, Ca, Mg and P than the overall mean values (Fig. 3ab). The distribution of Mg was antagonistic to Ca concentration in the leaves of both forests, i.e. where more trees showed low concentration of Ca, less trees recorded low concentration of Mg and *vice versa* (Fig. 2 and 3 and Table 1). Both elements are required for hydration regulation. Few experimental studies have been devoted to the specific nutrient requirements of wild plants and comparative analyses might help to elucidate the causes underlying characteristic floristic distribution patterns (Walter, 1995).

The two secondary forests soils indicated that K, Ca, Mg and N concentrations were significantly higher in the AS than in the DS within 0–15 cm and 15–30 cm soil depths ($P < 0.05$) (Table 2). Phosphorus in the soil was highest in DS at 0–15 cm and least in AS at 30–45 cm soil depth (3.37 and 0.25 mg kg^{-1}, respectively ($P < 0.05$). Potassium and N concentrations were very low beyond 15 cm soil depth in DS (0.11~ 0.98 g kg^{-1}, 0.36 ~ 0.62 gkg^{-1}, respectively). The principal nutrient elements of Ca, Mg, K and P concentrations were higher at 0–15 cm than further down the soil depths within the secondary forests. However, N at 45-60 cm (2.24 g kg^{-1}) was the highest in AS whilst N was the highest at 0–15 cm in DS (4.29 g kg^{-1}) (Table 2). Leaching and/or denitrifica-tion losses of N may have occurred much more in AS than in DS.

TABLE 2

Mean total nutrients concentrations in soils at different depths in Akyaakrom (AS) and Dopiri (DS) secondary forests.

Site	*Soil series*	*Depth (cm)*	*N* g kg	*Available P* mg kg^{-1}	*K* g kg^{-1}	*Ca* g kg^{-1}	*Mg* g kg^{-1}

		0 –15	2.75 (a) *	1.08 (b)	2.57 (a)	6.12 (b)	10.53 (a)
		15 – 30	0.89 (b)	1.22 (b)	2.45 (a)	17.53 (a)	3.89 (b)
AS	Bekwai	30 – 45	1.40 (b)	0.25 (c)	2.14 (a)	3.05 (c)	7.31 (a)
		45 –60	1.40 (b)	1.06 (b)	2.14 (a)	7.95 (b)	1.68 (c)
		0 –15	3.30 (a)	3.37 (a)	6.02 (c)*	17.37 (a)	12.22 (a)
		15 – 30	3.15 (a)	0.43 (c)	0.98 (b)	2.34 (c)	4.49 (b)
DS	Nzima	30 – 45	2.20 (a)	1.26 (b)	0.13 (b)	2.89 (c)	5.41 (b)
		45– 60	3.70 (a)	1.09 (b)	0.11 (b)	2.66 (c)	5.85 (b)

* Means with the same letters in parenthesis within a column were not significantly different at $P < 0.05$

The conversion of nutrient balance into land quality indicator was reported by Pieri *et al.* (1995). Nutrient balance is one of the major characteristics of a tropical rain forest area that determines whether or not a forest can be utilized on a sustainable basis (Cole, 1995; Stoorvogel, 1993; Whitmore, 1990). Land quality indicators for each of the secondary forests were determined for each element. Based on the fact that the soil serves as nutrient source for plants, Walter (1995) stated that mineralization occurs during the biological breakdown of organic matter. The concentration of nutrients in the tissues and not the quantity is important. Actual amount of nutrients available can vary over wide ranges without any noticeable effects on yield (Walter, 1995). From Fig. 4, the land quality indexes of the nutrient elements of N, P, K, Ca and Mg were higher in AS than in DS. This may have been the index for the high tree species density and diversity recorded in AS than in DS.

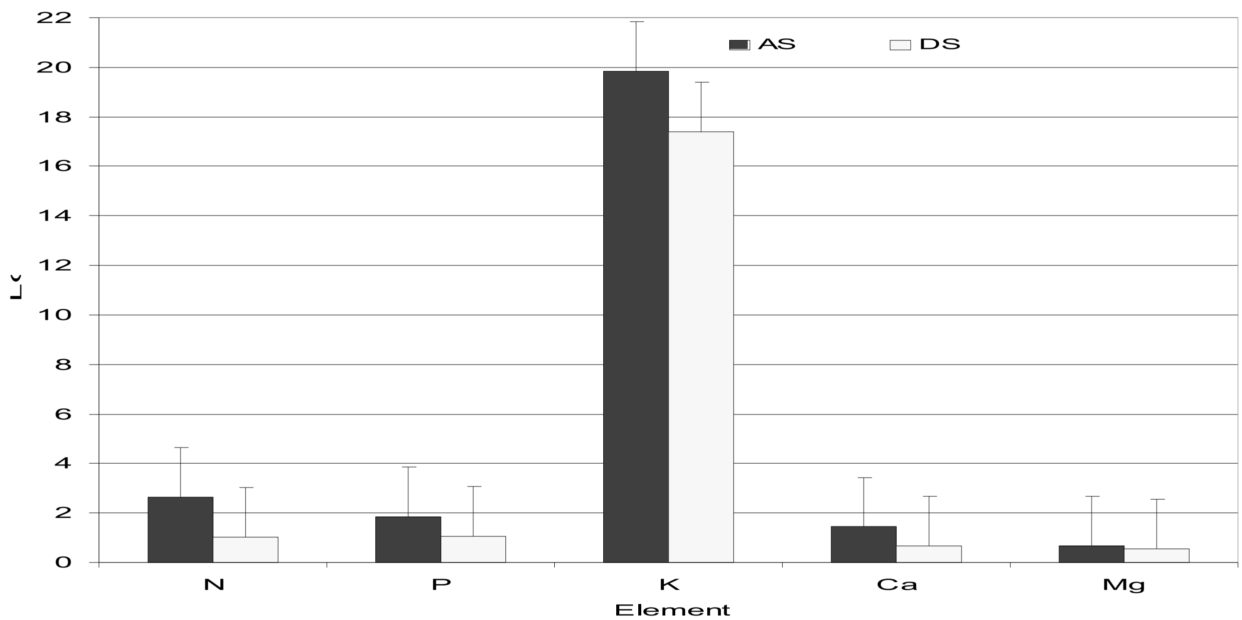

Figure 4. Land Quality Index (LQI) for Akyaakrom (AS) and Dopiri (DS) secondary forests

Vertical bars indicate error bars ($P < 0.05$)

Conclusion

The ameliorating effects of trees on the ecosystem vary with tree species, soil type and silvicultural practices. The high tree diversity in AS may have contributed to high rate of litter fall and decay leading to better nutrient cycling to support plant growth. The information generated may be useful for the different tree species associations and combinations that would lead to the integration of agroforestry practices for sustainable and increased agricultural productivity and environmental conservation in Ghana.

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