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The effect of aboveground biomass removal on soil macronutrient over time in Munesa Shashemane, Ethiopia

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Abstract

This study aims to compare the proportion of macronutrients in different parts of the aboveground biomass; and to estimate the amount of macronutrient loss from continuous farmlands (mechanized farm and traditional farm) and plantation stands (*Cupresus lusitanica* and *Eucalyptus saligna*) through harvesting. From 20 × 20 m^2 sized sample plots, a representative samples were collected from leaf, branch and stem of the plantation stands. Macronutrient analyses were carried out for the samples taken from plantations and maize crops on continuous farmlands. All data collected were subjected to ANOVA using the general linear model of SAS 9.0 at $P < 0.05$. The results of macronutrient in aboveground biomass of maize in the continuous farm lands shows that, the grain component contained as much as 50% of N and 60% of P compared to leaf and stem. However, a high proportion of K, Ca, and Mg were found in the leaf and stem components. In the case of *C. lusitanica*, 64.4% N, 70% P, 68.4% K, 65.3% Ca, and 68.75% of Mg was found in the stem compared to the leaf and branch. In the *E. saligna*, the stem contained 22% N, 30% P, 11.8% K, 26.6% Ca, and 12.5% Mg; with the remaining proportion of each nutrient found in the leaf and branch. Based on the results, much of the nutrients can be removed through the leaf and stem removal in the continuous farmlands. Complete removal of the biomass with little residue returned to the soil, for long periods under plantation land use, may also lead to macronutrient depletion. Therefore, to minimize this effect, the aboveground biomass harvest should focus on grain only on the farmlands, and stem only on the plantations.

Introduction

Tropical forest plantations are the most productive ecosystems in the world due to their fast growth (Binkley and Ryan 1998). Fast-growing trees have the ability to accumulate high amounts of nutrients in their biomass but may cause nutrient depletion in the soil. The studies conducted by Binkley and Ryan (1998) on the stands of *E. saligna* and *Albizia facaltaria* state that at stand age of 16 years, *Eucalyptus* plots had accumulated about 323 Mg/ha of aboveground biomass, and this was about 50% more than *Albezia* which had accumulated about 216 Mg/ha aboveground biomass. Some plant species shed their foliage in the dry season and release nutrients to the soil surface through mineralization while some evergreen species keep it in the leaf biomass for a longer period. The nutrient accumulation in the plant body also varies between different tree parts. The study conducted on *E. grandis* by Tiarks et al. (2004), shows that the fraction of macronutrients in utilizable stem wood is small as compared to total reserves at the site. The crown and bark accounts for the highest proportion of the nutrients that is, about 54% to 82% of the aboveground biomass macronutrient pools. The below-ground biomass remains in the soil and returns nutrients through decomposition of root debris whereas the aboveground biomass is almost always harvested. If not only logs, but also branches and twigs, are used as fuel wood, most of the nutrients will be lost and not returned to the soil nutrient store as when decomposed in situ. The forest floor contains large

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quantities of N, P, and Ca relative to the nutrients in the entire system (Tiarks et al. 2004). If left at site, they could also contribute to the formation of soil organic matter which is important for storing nutrients in the soil (Schroth and Sinclair 2003).

Among nutrient cycling processes, nutrient retranslocation becomes an important component of the cycle as the tree biomass increases over time (Bowen and Nambiar 1984). In order to understand nutrient cycling processes and evaluate site quality changes in a forest ecosystem, it is very important to know the nutrient distribution among different parts of the plant biomass.

Plant biomass contains different proportions of nutrients in different parts of the plant body. This implies that the soil nutrients can be affected differently depending on the parts of the plant biomass being harvested. In a tropical rain forest biomass, a high proportion of nutrients are found in the bark and foliage; with an equal proportion occurring in the litter. As much as 54% and 82% of the aboveground biomass macronutrient pools are found in the crown and bark fraction (Tiarks et al. 2004). The study on C, N, and P allocation in agro-ecosystems conducted between 1993 and 1997 in high Casamance, in southern Senegal reveals that the plant biomass in the crop and fallow plots contained 18 Mg C, 0.25 Mg N, and 0.02 Mg P/ha; of which more than 40–50% were stored in the aboveground woody biomass (Manlay et al. 2001).

Continuous land cultivation, without sufficient nutrient input, is the major reason for soil quality decline in most of sub-Saharan Africa (Buresh et al. 1997). This is related to two major factors; (1) the lack of financial capital in households, that hinders farmers' ability to purchase sufficient amounts of fertilizer; (2) shrinking land holdings, that leads to deforestation and increased reliance on crop residues for fuel and animal fodder, thus preventing input of organic residues to the soil. However, some of the nutrients removed for animal fodder and fuel wood can be returned back to the soil through intensive management of the manure and household waste (Lupwayi et al. 2000). In a study undertaken to investigate the contents of manures from six experimental stations and twenty small-scale farms in the Ethiopian highlands, the manures contained on average, 21.3 g K, 18.3 g N, 16.4 g Ca, 5.6 g Mg, 4.5 g P, 10.8 g Fe, 0.78 g Mn, 0.09 g Zn (Lupwayi et al. 2000).

A study conducted in West Africa on the differential N uptake by maize cultivars, and soil nitrate dynamics under N fertilization, indicated that N uptake was highest at the early stage of the plant stem elongation growth phase. The high aboveground dry-matter accumulation and low soil total N at crop maturity correlates with the aboveground biomass and total N uptake among tropical maize populations, with the soil N concentration (Lafitte and Edmeades 1994; Oikeh et al. 2003). Increased nutrient removal associated with harvesting crop residue for biofuel or other bioproducts has a short-term economic impact and a potential long-term impact sustainable land use system (Hoskinson et al. 2007). At the site where this study was made, the maize stover and the branches and twigs of the plantation trees are used for fuel wood and animal feed to some extent. Therefore, this study was aimed at comparing the proportion of macronutrients in different parts of the plant's aboveground biomass in four land use types; and to estimate the amount of macronutrient loss from these lands use types through harvesting.

Materials and Methods

The farmlands come from the conversation of natural forests. After some years of continuous cultivation, inorganic fertilizer is being added in the form of urea and Diamonium phosphate (DAP), at an approximate rate 50 kg/ha/year for each of the two fertilizers, in traditional farmlands. However, some farmers cannot afford to apply the recommended amount and do not use any fertilizers at all. The mechanized farming (MF) site has been plowed since 1968 and wheat, barley, and maize were cultivated as the major crops in rotation with the use of a fertilizer at a maximum rate of 100 kg/ha/year of urea and DAP, respectively, since clearance of the natural forest, and converted in to crop cultivation and tree plantations.

To determine the aboveground biomass, macronutrients under these farmlands, that is, mechanized (MF) and traditional farm (TF), a 20×20 m^2 plot was selected and subsampled to 1×1 m^2 at each corner and at the center. All of the maize (*Zea mays*, L.) crops in these five subsample plot areas were harvested, and the fresh weight was measured. Representative samples from the stem, leaf, and grain were then taken to give a total of 5×3 samples from both farmlands.

The fresh weights for each of the biomass components under each land use were recorded and allowed to oven dry at 65 ± 5°C for 24 h. The dry mass of each biomass component was calculated by using the formula as stated by Chidumaya (2009) as follows:

Dry mass = (subsample dry weight/subsample fresh weight) × fresh weight of the whole sample. And then, the expansion factor = 10, 000/area of plot in m^2 was used to convert it to hectare basis.

A total of 30 samples were analyzed for macronutrient (N, P, K, Mg, and Ca) concentration in the aboveground biomass of the maize crop. Plant nutrient concentrations were determined on each plant component at each sampling site. The air-dried samples, from the leaf, grain, and stem, were ground to pass through a 2-mm sieve.

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Dried and ground samples were wet digested. The N concentration was analyzed with a LECO TruSpec total combustion system. The P, Ca, Mg, and K were analyzed by using inductively coupled plasma atomic emission spectrometry "(ICP-AES)". The amount of macronutrient contained in the aboveground biomass of the maize crop was calculated with the help of measured nutrient concentrations, and the amount of biomass corrected for water content to a dry weight basis.

To determine the aboveground biomass macronutrients in plantation stands, developing biomass equations is a laborious work that requires considerable effort, time, and money for collecting the data. Once established, they can be used to estimate forest biomass. There are published equations for forest biomass assessment (Abate 2004; Aboal et al. 2005; Cole and Ewel 2006; Arevalo et al. 2007; Gil et al. 2010). The choice of equations depends on the applicability to the objective of the specific study, i.e., factors determining such as geographic location, land cover type/similarity in species, and forest management practices (DeGier 2003; Zewdie et al. 2009).

Hence, the aboveground biomass for the two plantations (*C. lusitanica* and *E. saligna*) was estimated by measuring DBH and height of all trees on a 20 × 20 m^2 sample plot from each of the plantation stands. For *C. lusitanica*, the aboveground biomass was calculated based on the already developed allometric functions taking DBH as an independent variable. For three different plant parts of *C. lusitanica*, the linear regression model developed at Munesa Shashemane was adopted according to Abate (2004). Hence, the three equations (dry weight (kg) of leaf is = 1.36 × DBH (cm) − 19.84) with R^2 = 0.91, dry weight (kg) of branch is = 3.61 × DBH (cm) − 61.23 with R^2 = 0.96, and dry weight (kg) of stem is = 22.32 × DBH (cm) − 299.05 with R^2 = 0.91) were used.

For *E. saligna*, the aboveground biomass of the trees was estimated by adopting the dry weight predictive allometric equation which was developed on the same study area based on the height (m) and DBH (cm) as reported by Teklu (1997). Thus, $\ln W = \ln b_0 + b_1 \ln \mathrm{DBH} + b_2 \ln H$; Where W stands for dry weight of *E. saligna* (kg), ln stands for natural logarithm, b_0, $b_{1,}$ and b_2 stands for the regression coefficients.

From each sample plot, one sample tree, having an approximately mean value of all the trees by height and DBH, was selected. After felling three selected trees in each plantation stand, it was separated in to stems, branches, and leaves as suggested by Abate (2004). Each stem was cut into three equal logs and 5-cm thick discs were cut from each log. The branches and leaves were subsampled as belonging to the upper, medium, and lower third of the crown. Then the samples that were taken from each part of the trees were bulked together to produce three representative samples, from each part of the trees. The bulked samples taken from the stems, branches, and leaves, in three replications from both plantations, give a total of nine samples (3 replication × 3 treatments (branches, leaves, and stems)) from each plantation for macronutrient analysis.

Samples from all components were ground for macronutrient analysis. The elemental analysis was carried out by focusing on some of the macronutrients (N, P, K, Mg and Ca) in the aboveground biomass. The samples were analyzed for N concentration with a LECO truSpec analyzer. The P, Ca, Mg, and K were analyzed by using inductively coupled plasma atomic emission spectrometry "(ICP-AES)". To calculate the amount of macronutrients in the aboveground biomass of *E. saligna* and *C. lusitanica*, the mean element concentrations per tree component were multiplied by their respective mean dry biomass to determine the amounts of nutrients in the sampled tree components. Mean nutrient values of the whole tree were calculated on a per plot and per hectare basis.

The statistical analyses for the aboveground biomass macronutrient concentrations in the crop compartments (leaf, grain, and stem) and tree compartments (leaf, branch, and stem), and between land uses (MF, TF, *E. saligna*, and *C. lusitanica)* were carried out by using the software SAS 9.0 and the two-way ANOVA was computed at $P < 0.05$.

Results and Discussion

The total N concentration in grain, leaf, and stem did not vary significantly at $P < 0.05$ under MF, but under TF land use, the total N in grain, and leaf was significantly higher than that of stem. Under both MF and TF, the grain contained significantly higher concentrations of P than that of leaf and stem. Overall, higher concentrations of P were observed in the maize crop under MF compared to TF (Table 1). Under MF, the stem contained significantly higher and the grain significantly lower concentrations of K. Significantly higher concentrations of K were observed in the maize crop under MF compared to TF (Table 1). Although, the maize crop under MF contained a significantly higher concentration of Ca compared to TF (Table 1), the leaves had the highest concentrations followed by stem and grain under both farmlands. Regarding Mg concentration, the grain contained a significantly lower concentration under TF.

The variation in nutrients in different crop parts indicates the direction to concentrate on in managing soil properties, by managing residues from different crop components. According to the macronutrient concentrations observed in the aboveground biomass of the maize

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Table 1. Mean macronutrient concentration (SD) in different plants parts of a maize crop under MF and TF. Means followed by different letters by column are significantly different at $P < 0.05$.

Plant parts		TN (g/kg)	P (g/kg)	K (g/kg)	Ca (g/kg)	Mg (g/kg)
MF	Grain	11.8 (4.50)[a]	2.67 (0.44)[a]	5.75 (0.66)[c]	2.95 (0.94)[c]	1.72 (0.31)[a]
	Leaf	11.0 (1.70)[a]	1.54 (0.44)[b]	12.2 (1.58)[b]	18.3 (2.88)[a]	2.51 (0.61)[a]
	Stem	7.10 (3.20)[a]	1.05 (0.57)[b]	21.1 (4.99)[a]	9.96 (0.89)[b]	2.39 (0.60)[a]
	Overall	9.97[a]	1.75[a]	13.02[a]	10.4[a]	2.21[a]
TF	Grain	12.7 (1.30)[a]	2.21 (0.34)[a]	5.70 (0.48)[a]	1.87 (0.88)[c]	1.15 (0.26)[c]
	Leaf	12.6 (2.40)[a]	1.16 (0.20)[b]	11.0 (2.87)[a]	15.9 (1.78)[a]	2.72 (0.48)[a]
	Stem	6.30 (3.00)[b]	0.58 (0.12)[c]	9.65 (5.14)[a]	9.17 (0.46)[b]	2.27 (0.28)[a]
	Overall	10.53[a]	1.32[b]	8.78[b]	8.98[b]	2.05[a]

Table 2. Estimated total amount of macronutrient in different plant parts of a maize crop under mechanized (MF) and traditional (TF) farm lands.

	Plant parts	N (Mg/ha)	P (Mg/ha)	K (Mg/ha)	Ca (Mg/ha)	Mg (Mg/ha)
MF	Leaf	0.4	0.06	0.42	0.67	0.09
	Grain	0.47	0.11	0.24	0.12	0.07
	Stem	0.08	0.01	0.24	0.12	0.03
	Total	0.95	0.18	0.9	0.91	0.19
TF	Leaf	0.28	0.03	0.24	0.35	0.06
	Grain	0.42	0.08	0.19	0.06	0.04
	Stem	0.15	0.01	0.25	0.24	0.06
	Total	0.85	0.12	0.68	0.65	0.16

Where, MF is for Mechanized, and TF is for Traditional farm respectively.

crop (Table 1), P concentration can be significantly affected by grain harvest under both MF and TF. The K concentration can be affected at a higher rate with stem harvest than that of grain and leaves under MF. A higher concentration of Ca can be removed from the soil with leaf export compared to grain and stem.

The macronutrient contents presented in Table 2 indicates that in comparison between MF and TF, the maize crop biomass under MF contained higher amounts of all the studied macronutrients. With a higher rate of mineral N fertilizer application, the P, Ca, and Mg uptake by maize aboveground biomass were significantly increased (Yu et al. 2009). The higher K content in the crop biomass could be attributed to the P and N fertilization under MF land, as NP treatment enhances a greater uptake of K by crops (Yu et al. 2009). Since there is no fertilization with K, the higher quantities of K may have been released from the reservoir pool with the help of NP fertilization. Fertilizer management practices through the addition of higher N and P in the fields resulted in a higher nutrient content in grain and in the aboveground biomass as a whole at harvest (Yu et al. 2009).

The macronutrient concentration in the crop biomass varies between the plant components. If a macronutrient is highly concentrated in a specific plant part, then the removal of that plant part has a pronounced effect on the soil nutrient balance. Under TF, 49.4% N and 66.7% P; and under MF 49.5% N and 61.1% P was contained in the grain. During the grain harvest, a higher proportion of these nutrients can be removed (Table 2). However, for the other macronutrients investigated, the harvesting of only the grain may not bring a severe loss from the soil nutrient budget. For instance, under TF, the grain contained only 27.9% K, 9.2% Ca, and 25% Mg. Under MF, the grain contained only 26.5% K, 13.2% Ca, and 36.4% Mg. This indicates that only harvesting the grain part, whilst retaining the leaves and stems back on the field may return 72.1% K, 90.7% Ca, and 75% Mg under TF and 73.3% K, 86.8% Ca, and 63.2% Mg under MF. As shown by Mapfumo and Mtambanengwe (undated), from the 73 kg/ha of K stored within the plant in the study site, an average of 72% is stored within the stalks, leaves, and husks. The study by Blanco-Canqui and Lal (2008) indicated that stover removal resulted in a consistent decrease in K^+ from the soil with ≥75% of K content removed in crop residues. They also reported that stover removal leads to a decline in the total SOC pool, total N pool, and the available P concentration at a soil depth of 0–10 cm.

Crop management activities play an important role in the soil nutrient balance. Of the amount of macronutrients lost by the aboveground biomass, removal under continuous farmland uses, only N and P were higher in grain harvest. The K, Ca, and Mg were found in higher amounts

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in the leaf and stem and lower in grain. The results suggest that if at harvest only the grain part of the crop was removed, and the other crop residues returned to the soil, it would have a much less negative effect on the soil base cation budget than on N and P. Soil management through the management of the biomass harvest during each growing season has an important role in ensuring long-term soil fertility. A study conducted in Mexico which reported that highly declined soil fertility values are recorded in maize cultivation with 12 years of monoculture indicates that the age of land use for specific purposes, with low amounts of residue returning to the site, can cause soil fertility depletion (Marroquin et al. 2005).

The leaves of *C. lusitanica* and *E. saligna* contain significantly higher concentrations of total N, P, K, Ca, and Mg than other tree parts (Table 3). This is in line with the finding of Zewdie et al. (2009) on the *E. globulus* plantation trees where nutrient concentrations (N, P, K, Ca, and Mg) followed the order: leaves > stemwood > stembark > twigs > branches. Thus, the leaf of the plantation species is more important compared to other plant components for the conservation and recycling of macronutrients in the soil. Comparing the two plantation species, it is expected that under *C. lusitanica,* soil Mg may be more sensitive to the aboveground biomass removal than under *E. saligna* due to the differences in concentration.

The amount of macronutrients in plant aboveground biomass may be dependent on the age of the plantation. A high proportion of nonutilizable biomass will be produced if the trees are harvested at a young age or by harvesting compartments with high densities (Tiarks et al. 2004). Likewise with the trees of *E. saligna,* stand of one to three trees per stool contained higher aboveground biomass macronutrients in the nonutilizable components. This may be attributed to the relatively short rotation period of the trees leading them to have a higher vegetative part and less biomass accumulation in the stem part. A study by Zewdie et al. (2009) on *E. globules* indicated that total aboveground biomass increased from 11 t/ha at a stand age of 1 year to 153 t/ha at 9 years of which the highest dry weight was allocated to stemwood. For these reasons, the frequent harvest of the nonutilizable part of *E. salinga* trees is more drastic to the soil nutrients.

The *C. lusitanica* aboveground biomass in the present study shows a greater share of macronutrients was contained in the stem (Table 4). This may be related to the higher biomass allocation to the stem in relation to the tree's age. As reported by Abate (2004) for about 34 year old *C. lusitanica* stand, 85% of the aboveground biomass was allocated to the stemwood, 11% to the branches, and the remaining 4% was allocated to the foliage. A high proportion of the aboveground biomass is in stemwood, particularly in trees of larger diameter, where the stemwood contained more than 50% of the aboveground biomass, followed by twigs and branches. A study made in an Amazonian forest for nutrient distribution in plant components also reported that the accumulation of biomass was higher in the stem than other plant components (Stark 1971). The stem biomass of *C. lusitanica* stand of 25 years old showed that the highest content for all macronutrients investigated were found in the stem. Since the greater part of the biomass is found in the stem (Table 6), even low concentrations result in export of high amounts of nutrients through stem harvest. A study undertaken in a tropical natural forest indicated that a large nutrient loss occurred through the stem harvest since the largest amount was found in the stem followed by branches, root, and leaves. Among the nutrients, loss of K was largest followed by N, Mg, Ca, and P (Shanmughavel et al. 2001).

The differences in the amount of nutrients in different plant components give important information about the soil nutrient loss from the sites, through uptake by the biomass and subsequent harvesting of that plant part. The nutrient loss from the soil under vegetation cover can mainly be attributed to the plant parts harvested or consumed on site. Harvesting the biomass of whole trees

Table 3. Mean macronutrient concentration (SD) in different plant parts of *Cupresus lusitanica* (CL) and *Eucalyptus saligna* (ES). Different letters are significantly different at $P < 0.05$.

Plant parts		TN (g/kg)	P (g/kg)	K (g/kg)	Ca (g/kg)	Mg (g/kg)
C. lusitanica	Branch	3.80 (1.10)^{b}	0.38 (0.06)^{b}	2.02 (0.87)^{b}	4.26 (1.49)^{b}	0.75 (0.07)^{b}
	Leaf	19.6 (3.30)^{a}	1.70 (0.50)^{a}	9.50 (0.50)a	17.9 (4.95)^{a}	2.70 (0.54)^{a}
	Stem	2.47 (0.30)^{b}	0.28 (0.03)^{b}	1.50 (0.20)b	4.02 (0.63)^{b}	0.48 (0.08)^{b}
	Overall	8.62^{a}	0.79^{a}	4.34^{a}	8.73^{a}	1.31^{a}
E. saligna	Branch	4.20 (2.30)^{b}	0.29 (0.06)^{b}	1.02 (0.03)^{b}	3.97 (0.68)^{b}	0.21 (0.03)^{b}
	Leaf	16.6 (3.60)^{a}	1.39 (0.11)^{a}	11.8 (0.95)^{a}	22.7 (1.55)^{a}	1.49 (0.24)^{a}
	Stem	2.40 (0.70)^{b}	0.29 (0.10)^{b}	0.66 (0.31)^{b}	3.84 (0.83)^{b}	0.11 (0.08)^{b}
	Overall	7.73^{a}	0.66^{a}	4.49^{a}	10.2^{a}	0.6^{b}

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Table 4. Estimated total amount of macronutrient uptake by different plant parts in the *Cupresus lusitanica* and *Eucalyptus saligna* biomass.

	Plant parts	Dry biomass (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Ca (kg/ha)	Mg (kg/ha)
C. lusitanica	Leaf	11,300	220	20	110	200	30
	Branch	26,000	100	10	50	110	20
	Stem	233,600	580	70	350	400	110
	Total amount (kg/ha)		900	100	510	710	160
E. saligna	Leaf	700	11.7	1	8.4	16.1	1.1
	Branch	120	5.3	0.4	1.3	4.9	0.3
	Stem	2000	4.8	0.6	1.3	7.6	0.2
	Total amount (kg/ha)		21.8	2	11	28.6	1.6

may have a considerable impact on the soil nutrient budget. From the total macronutrients investigated for *C. lusitanica* (Table 6), although harvesting the stem has the highest effect on the soil macronutrient nutrient budget, leaving the branches and leaves on the site has a positive impact on the soil nutrient balance. For instance, 35.6% N, 30% P, 31.6% K, 34.7% Ca, and 25% Mg were contained in the leaf and branch parts of *C. lusitanica* and contributed to the soil nutrient pool if left on the site. Results from an *E. globulus* plantation indicated that, 67.5% of the N and 33.6% of the P were contained in the biomass of stem bark, branches and leaves, and that 56.6% of the K and 59.2% of the Ca were contained in components other than the stem (Gil et al. 2010). From the total macronutrients investigated for *E. saligna* (Table 4), 78% N, 70% P, 88.2% K, 73.4% Ca, and 87.5% Mg were contained in plant components other than the stem. Hence, more can be returned to the soil under *E. saligna* by leaving the branch and leaf biomass on the site.

Harvest management should consider the export of nutrients and try to adopt a sustainable nutrient management approach on the site, since the soil nutrient pool, plant growth, and soil degradation are all related through nutrient uptake, and intensive export of biomass may deplete the soil nutrients. Crop residues like litter, bark, and branches are considered as contributors to the soil nutrient pool. The study by Gil et al. (2010) indicated that with the plantation management option to harvest only stem wood, the amount of K removal could be as low as 43.4%, of Ca as low as 12.7%; and of Mg as low as 35.5%. The study by Tiarks et al. (2004) on *E. grandis* also indicated that by leaving the stem bark and all fractions of the crown on the site, nutrient export can be minimized. Abate (2004) has recommended that in order to make the plantation forests sustainable, the silvicultural practice in the future should consider on-site conservation of foliage and bark.

The removal of leaves, twigs, and other understorey biomass for fuel wood may have contributed to the removal of some macronutrients in the study area. The harvest intensity under the *E. saligna* was high in the study site. The leaves, branches, and twigs were removed as fuel wood by the local people after the stem harvest in the area was sold in the local market for their livelihood (Poultouchidou 2012). As a result, high amounts of nutrients may have been removed through these plant parts. The intensive and regular removal of plantation forest floor litter may be used as an important reason for substantial loss of nutrients from the site (Gil et al. 2010).

Conclusion and Recommendation

The N and P were found to be higher in the grains of maize and there is a high probability of being lost through harvesting the grain. However, the Ca, Mg, and S can be returned to the land with the corn stover through decomposition on the farm land since a higher concentration of these macronutrients was observed in the stover. Although the proportion of N and P is lower in the stover of maize crops compared to Ca, Mg, and K, the residue management during harvesting can still minimize the mining of these critical macronutrients in farm lands.

In spite of the higher aboveground biomass for *C. lusitanica* in the stem during harvesting, returning other parts of the tree to decompose in the site can reduce the loss of the studied nutrients. Regarding *E. saligna*, a higher proportion of the nutrients were found in the leaf and branch parts, and therefore the removal of branches, leafs, and twigs may have a high impact on the studied soil macronutrients. In general, knowledge of biomass nutrient partitioning and the impact of export of macronutrients through the aboveground biomass harvest is very important for the long-term success of production. Since different plant parts contain different amounts of nutrients,

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complete removal of the biomass for a long period from crop land and plantation stand may lead to nutrient depletion. Therefore, it is advised to retain the corn stover on the farmlands; and twigs and litter on the tree plantations to minimize the loss of macronutrients and thus prevent further degradation of the site.

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Conflict of Interest

None declared.

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