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Tel: (233) 51 60123 / (233) 51 60373
Fax: (233) 51 60121
E-mail: oamoako@forig.org

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LITTER-FALL AND NUTRIENT RETURN IN GME. LINA ARBOREA SHORT ROTATION WOODLOT: IMPLICATIONS FOR SITE PRODUCTIVITY

C. ADU-ANNING1*, E. Y. SAFO2 & E. A. ABENEY3

1Department of Agroforestry, 2Department of Crop Science, 3Department of Silviculture & Forest Management, Kwame Nkrumah University of Science & Technology, (KNUST), Kumasi (*Author for correspondence: Department of Agroforestry, KNUST, Kumasi, Ghana, E-mail: canning_01@yahoo.com)

ABSTRACT

The amount of litter produced and nutrients returned to the forest floor in Gmelina arborea (Royle) short rotation woodlot were monitored for 12 months. The trials were planted with 400-25 trees within treatment plots, each measured 12m x 12m or 27,777 – 1,736 trees/ha and harvesting was done after the litter fall monitoring. The results showed that litterfall and the subsequent amount of nutrients returned to the forest floor, increased with increasing planting density. The differences in both cases were significant (P<0.001). The annual litter-fall ranged from 1.2 to 8.1 t/ha of which leaves were the dominant components with the proportions of other components being insignificant. Total N, P, K, Ca and Mg returned were 106, 11, 117, 76 and 32 kg/ha respectively. Over 60% of total annual litter-fall occurred during the dry season. The pattern of nutrient retranslocation from the leaves showed that all nutrients except calcium were significantly retranslocated. Therefore, to reduce the impact of tree harvesting on site nutrient status and also to ensure sustainable production of wood, harvesting should be done at a period of low nutrient levels in the leaves. The reason being most of the nutrients might have been transferred into storage organs like the roots through processes like retranslocation. This, it is believed, could ensure a sustainable production system, and also efficiency of the nutrient cycling process.

Keywords: Afram headwaters, derived savanna, nutrient content, retranslocation, spacing, West Africa

INTRODUCTION

Nutrients are one of the important factors other than water and light energy controlling plant growth and productivity (Jordan, 1985). Through litterfall and its subsequent decomposition, essential nutrients in the soil are made available to trees. Therefore, the maintenance of soil fertility in tropical ecosystems is partly achieved by the high and rapid circulation and recycling of nutrients through litter-fall and decomposition (Ola-Adams & Egunjobi, 1992; Sundarapandian & Swamy, 1999). Besides, in deciduous trees, the resulting reduced rate of transpiration associated with leaf fall becomes an added advantage (Vitausk, 1984; Ola-Adams & Egunjobi, 1992; Warren & Zou, 2002).

In short rotation monocultures, the quantity of litter returned to the forest floor is an indication of the replenishment of fertility of the soil after harvesting. More important is nutrient conservation process through retranslocation. Retranslocation of nutrients is believed to ensure continuity of the nutrient cycling process and also

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provide nutrients for early growth of new shoots (Katainen et al., 1985; Kathryn, 2000).

The quantity of litter in the various land use systems in the tropics has been measured and the results have been summarised (Vitousek, 1984; Lonsdale, 1987; Ola-Adams, 1992). The present study therefore evaluates the effects of spacing regime on the rate and amount of litter fall and nutrient content and nutrient retranslocation in *Gmelina arborea* high-density short rotation woodlot.

**METHODOLOGY**

**Experimental Site**

The experiment was carried out near Asempaneye in the Aframie headwaters Forest Reserve. It is situated between latitudes 7° and 7° 15'N and longitudes 1° 48'. The area lies within the tropical humid lowland climatic zone, which is characterised by pronounced seasonality (Hall & Swaine, 1981). There is a hot, dry harmattan season from December to February characterised by desiccating winds (the North East Trade winds). This phenomenon is followed by a prolonged wet season with bimodal peak rainfall in June and October. The mean annual rainfall in the area according to ODA/FD (1989) is approximately 1,250mm.

Diurnal humidity rises in early mornings and late evenings while the afternoons are usually dry. The soil formations present in the area are developed from the upper and lower Birrimian rocks, granites and Upper Voltaian sandstones (Brammer, 1962). These give rise to acrisols, nitisols and luvisols. Fluvisols and gleysoils are also found in valley bottoms and along riparian areas (Brammer, 1962). The soil in the experimental site is basically nitisol and the associations present are Bediasi-Sutawa, Bekwai-Nzema and Kumasi-Asuansi (Adu-Anning, 2000).

The physical and chemical properties of the soil are presented in Table 1.

**Experimental Design**

Four spacing treatments and three cutting cycles were combined in a randomised block design. The treatments were in a factorial combination of spacing (S) and cutting cycles (Y) as follows:

<table>
<thead>
<tr>
<th>Spacing</th>
<th>Planting density/plot (hectare)</th>
<th>Cutting cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>S₁ = 0.6m x 0.6m</td>
<td>400 (27.778)</td>
<td>Y₁ = Cut every two years</td>
</tr>
<tr>
<td>S₂ = 1.2m x 1.2m</td>
<td>100 (6,944)</td>
<td>Y₂ = Cut every three years</td>
</tr>
<tr>
<td>S₃ = 1.8m x 1.8m</td>
<td>44 (3,086)</td>
<td>Y₃ = Cut every four years</td>
</tr>
<tr>
<td>S₄ = 2.4m x 2.4m</td>
<td>25 (1,736)</td>
<td></td>
</tr>
</tbody>
</table>

**Litter fall**

Five (S) litter trays with nylon mesh floor (0.5m x 0.5m x 0.15m) were randomly distributed in every treatment plot and thereafter monitored for 12 months. The trays were slightly raised above the ground with pegs 25cm to avoid contact with the soil. Litter was collected from each tray at monthly intervals except during the rainy period in which it was done on fortnightly basis to reduce losses through decomposition (Songwe et al., 1995). The litter collected was weighed and oven-dried at 70°C to constant weight, and then calculated on per hectare basis. The litter was then sorted into leaf, branch and flower or fruit where necessary, reweighed and expressed on per hectare basis. The N, P, K, Ca and Mg contents in the litter were analysed at monthly intervals using methods described below. Climatic variables, rainfall, temperature and humidity were also monitored using appropriate measuring equipment at the study site during the period.

Nutrient retranslocation from leaves was estimated using both matured green and senesced leaves (Rahlan & Singh, 1987; Lodhiyal et al., 1995b). One hundred each of green and senesced leaves were picked and oven-dried at 70°C to a constant weight. This was done on four occasions.
TABLE 1

Physical and chemical properties of the study site in the Derived Savanna Zone

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Mechanical Analysis %</th>
<th>pH 1:2.5 (H₂O)</th>
<th>Org. C %</th>
<th>Tota N %</th>
<th>Avail P mg/kg</th>
<th>Exchangeable Cations cmol/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sand</td>
<td>Silt</td>
<td>Clay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-10</td>
<td>86.7</td>
<td>8.8</td>
<td>4.5</td>
<td>5.9</td>
<td>1.19</td>
<td>0.07</td>
</tr>
<tr>
<td>10-20</td>
<td>83.1</td>
<td>11.3</td>
<td>5.6</td>
<td>5.9</td>
<td>0.84</td>
<td>0.04</td>
</tr>
<tr>
<td>20-30</td>
<td>83.7</td>
<td>11.6</td>
<td>4.7</td>
<td>5.7</td>
<td>0.70</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Source: Adu-Anning (2000)

The green as well as the senesced leaves were ground to pass through a 0.5mm sieve-mesh and analysed for N, P, K, Ca and Mg using the methods described below and quantities of retranslocated nutrients estimated using the formula as stated below: (Rahman & Singh, 1987; Lodhiyal et al., 1995b).

\[
\text{Retranslocation} = \frac{\text{Nutrient in mature green leaf (x)} - \text{Nutrient in senesced leaf (y)}}{\text{Nutrients in mature green leaf (x)}} \times 100\%
\]

Chemical Analysis of Samples

The dry samples of the litter were ground to pass through a 0.5mm-mesh sieve. Total nitrogen was measured by kjeldahl digestion (Bremner & Mulvaney, 1982). Phosphorus, potassium, calcium and magnesium concentrations were determined after dry ashing in a muffle furnace at 450°C for 8 hours. After cooling, the ash was digested with 1.0 M HCl determined using the Vanado-molybdate method (Association of Official Analytical Chemists, 1970). Potassium was determined using flame photometry and calcium and magnesium using the EDTA compleximetric titration method.

RESULTS

Pattern of Leaf Litter-fall

The season patterns of leaf litter-fall during the period under investigation for *Gmelina arborea* and the influence of some climatic conditions on litter-fall are shown in Figures 1 and 2 respectively. Leaf litter fell throughout the investigation period, and the rate of fall was particularly high in February. The litter-fall increased from August till it peaked in February before decreasing to the lowest in July. Between 37 and 47% of leaves fell between December and February, a period of no rain (Figures 1 and 2). The differences in the amount of leaf litterfall amongst spacing as well as amongst the month were significant (P < 0.001), Table 2. Again, the combine effects of spacing and the different months were also significant (P < 0.001), Table 2.
TABLE 2

Anova table for dry weight of leaf litterfall within four spacings, months and spacing/months interactions for Gmelina arborea

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>MS</th>
<th>F</th>
<th>P. value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spacing</td>
<td>3</td>
<td>26537.1</td>
<td>2759.7</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Month</td>
<td>11</td>
<td>3364.4</td>
<td>349.9</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Spacing/months Interaction</td>
<td>33</td>
<td>1300.4</td>
<td>135.2</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Error</td>
<td>96</td>
<td>9.62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>143</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1. Pattern of total monthly leaf fall in Gmelina arborea stand
Fig. 2. Total monthly rainfall and monthly mean maximum and minimum temperature in *Gmelina arborea* stand from August 1998 to July 1999.
Amount of leaf fall and climatic variables obtained from the study area were analysed using multiple regression. A significant negative correlation was observed between monthly leaf fall and relative humidity. On the other hand, non significant negative and positive correlations were observed between monthly leaf-fall with total rainfall and number of wet days in a multiple regression model:

\[ Y = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + a_4s_2 + a_5s_4 + a_6s_6 \]

Where

- \( Y \) = mean monthly leaf fall
- \( x_1 \) = total rainfall per month
- \( x_2 \) = Number of wet days
- \( x_3 \) = Relative humidity
- \( s_2 \) = 0.6m x 0.6m spacing
- \( s_4 \) = 1.2m x 1.2m spacing
- \( s_6 \) = 1.8m x 1.8m spacing
- \( a_0 \) = Intercept
- \( a_1, a_2, a_3, a_4, a_5, \) and \( a_6 \) are coefficients for \( x_1, x_2, x_3, s_2, s_4 \) and \( s_6 \) respectively.

Thus the multiple regression model obtained was:

\[ Y = 116.396 - 0.059x_1 + 1.343x_2 - 1.53x_3 + 56.95s_2 + 13.56s_4 - 0.422s_6 \]

\[ R^2 = 60\% \]

SEE = 21.2

However due to the weak relationship between \( Y \) and some of the independent variables i.e \( x_1, x_2, s_4 \) and \( s_6 \) the above model (1) was rewritten by regressing \( Y \) against \( x_3 \) and \( s_2 \) the strongest independent variables.

Thus the reduced model for Table 3 becomes:

\[ Y = b_0 + b_3x_3 + b_4s_2 \]

\[ \text{eq. (2)} \]

Where

- \( Y \) = mean monthly litter-fall
- \( b_0 \) = intercept
- \( x_3 \) = relative humidity
- \( b_3 \) = coefficient for \( x_3 \)
- \( s_2 \) = the lowest spacing

Thus the reduced model for equation (1) from Table 4 is:

\[ Y = 100.76 - 1.162x_3 + 52.57s_2 \]

\[ \text{eq. (3)} \]

\[ R^2 = 62\% \]

SEE = 21.20

**TABLE 3**

Multiple regression analysis between leaf fall/total rainfall, number of wet days and relative humidity in *Gmelina arborea* stand

<table>
<thead>
<tr>
<th>Variable</th>
<th>Co-efficient</th>
<th>SEE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>116.3955</td>
<td>33.17</td>
<td>0.001**</td>
</tr>
<tr>
<td>Total Rainfall</td>
<td>-0.05864</td>
<td>0.14</td>
<td>0.66ns</td>
</tr>
<tr>
<td>Wet days</td>
<td>1.342696</td>
<td>1.88</td>
<td>0.48ns</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>1.52608</td>
<td>0.54</td>
<td>0.007*</td>
</tr>
<tr>
<td>0.6m x 0.6m (s2)</td>
<td>56.95</td>
<td>8.65</td>
<td>0.001**</td>
</tr>
<tr>
<td>1.2m x 1.2m (s4)</td>
<td>13.555</td>
<td>8.65</td>
<td>0.13ns</td>
</tr>
<tr>
<td>1.8m x 1.8m (s6)</td>
<td>-0.42</td>
<td>8.65</td>
<td>0.96ns</td>
</tr>
</tbody>
</table>

**= significant (P < 0.001) or * (P < 0.05) R^2 = 65% , SEE = 21.8
Observations = 48 ns = not significant (P > 0.0)

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TABLE 4

Reduced multiple regression analysis between leaf fall and relative humidity in *Gmelina arborea* stand

<table>
<thead>
<tr>
<th>Variable</th>
<th>Co-efficient</th>
<th>SEE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercepsts</td>
<td>100.761</td>
<td>20.81</td>
<td>0.001**</td>
</tr>
<tr>
<td>Humidity</td>
<td>-1.162</td>
<td>0.28</td>
<td>0.001**</td>
</tr>
<tr>
<td>0.6m x 0.6m (s)</td>
<td>52.57</td>
<td>7.07</td>
<td>0.001**</td>
</tr>
</tbody>
</table>

** P < 0.001  R² = 62%  SEE = 21.20

TABLE 5

Mean nutrient concentrations in annual leaf litter-fall + SEE in *Gmelina arborea*

<table>
<thead>
<tr>
<th>Nutrient (%)</th>
<th>0.6m x 0.6m</th>
<th>1.2m x 1.2m</th>
<th>1.8m x 1.8m</th>
<th>2.4m x 2.4m</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>1.32±0.39</td>
<td>1.31±0.50</td>
<td>1.03±0.47</td>
<td>1.07±0.34</td>
</tr>
<tr>
<td>(107.0)</td>
<td>(37.8)</td>
<td>(12.5)</td>
<td>(13.5)</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.14±0.08</td>
<td>0.11±0.09</td>
<td>0.18±0.05</td>
<td>0.19±0.03</td>
</tr>
<tr>
<td>(116.71)</td>
<td>(3.18)</td>
<td>(2.19)</td>
<td>(2.4)</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>1.44±0.44</td>
<td>1.2±0.43</td>
<td>1.24±0.19</td>
<td>1.21±0.24</td>
</tr>
<tr>
<td>(116.71)</td>
<td>(34.65)</td>
<td>(15.10)</td>
<td>(15.26)</td>
<td></td>
</tr>
<tr>
<td>Ca</td>
<td>0.94±0.14</td>
<td>0.27±0.64</td>
<td>0.77±0.14</td>
<td>0.82±0.10</td>
</tr>
<tr>
<td>(116.71)</td>
<td>(36.68)</td>
<td>(9.38)</td>
<td>(10.34)</td>
<td></td>
</tr>
<tr>
<td>Mg</td>
<td>0.39±0.15</td>
<td>0.40±0.27</td>
<td>0.16±0.07</td>
<td>0.12±0.35</td>
</tr>
<tr>
<td>(116.71)</td>
<td>(11.55)</td>
<td>(1.95)</td>
<td>(1.51)</td>
<td></td>
</tr>
</tbody>
</table>

Values in brackets are nutrient equivalents in kg ha⁻¹ yr⁻¹
SEE = Standard Errors

**Nutrient Composition of Litter**

The concentrations of N, P, K, Ca and Mg in leaf litter for *Gmelina arborea* in various spacings are shown in Table 5. The variations in monthly nutrient concentrations during the period under investigation were considerable. The concentrations within the various spacings did not follow any pattern. The relative ranking of the nutrient concentrations were in the order: Ca>K>Na>Mg>P. The mean monthly nutrient concentrations for all nutrients tended to be high during the dry season but much higher for Ca during the same period.

The amounts of N, P, K, Ca and Mg in leaf litter (kg ha⁻¹ yr⁻¹) obtained from the study site are

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shown in Table 5. The amount of N, P, K, Ca and Mg in leaf litter in the various spacings were in the order K > N > Ca > P > Mg. Except for P, the concentrations of all others increased with decreasing spacing.

**Nutrient Retranslocation**

The retranslocation of nutrients (N, P, K, Ca and Mg) from *Gmelina arborea* within the various spacings are shown in Figures 3 to 6. The relative retranslocation percentages of these nutrients in the various spacings and ages differed. The retranslocation of nutrients in the various spacings were in the order 0.6m x 0.6m > 1.2m x 1.2m > 1.8m x 1.8m > 2.4m x 2.4m as shown in Figures 3 to 6. In the different ages the order was 2 years > 3 years > four years. Thus the percentage retranslocation from senescing leaves in *Gmelina* was higher for all nutrients except calcium and magnesium and tended to slightly decrease with age and increasing spacing. The nutrients retranslocated from *Gmelina* leaves were in the following order, 0.6m x 0.6m, 61 to 76% for N, 72 to 82% for P, 61 to 69% for K, 0% for Ca and 24 to 34% for Mg. Thus the ranking was P > N > K > Mg > Ca. The ranking in the other spacings did not follow any consistent pattern. The retranslocation rates were highly significant in both the spacing and cutting ages (P < 0.001, figures 3 to 6).

**Fig. 3.** Nutrient retranslocation in 0.6m x 0.6m spacing

**Fig. 4.** Nutrient retranslocation in 1.2m x 1.2m spacing

**Fig. 5.** Nutrient retranslocation in 1.8m x 1.8m spacing

**Fig. 6.** Nutrient retranslocation in 2.4m x 2.4m spacing
DISCUSSION

Pattern of Leaf Litter-fall

Leaf litter fell throughout the whole months under investigation and the rate was particularly high between December and March. Leaf fall was negatively correlated with climatic variables like total rainfall and relative humidity while it was positively correlated with number of wet days (Table 3). The major peaks as observed in the study were related to the dry periods when there were virtually no or little rain thus the peaks might be due to drastic reduction in rainfall leading to water stress which was suggested as the cause for the production of higher amounts of litter (Tanner, 1980). Similar observations had been made in other tropical countries like Nigeria (Nwoboshi, 1970; 1981b; Gong & Ong, 1983; Orinmoyegun, 1985; Ola-Adams & Egunjobi, 1992), Cameroon (Songwe et al., 1988) and Ghana (Tetteh, 1992).

The pattern of leaf fall also varied between the months and these would be related also to diurnal temperature ranges. The mean diurnal temperature range for November and March under the Derived savanna was between 16 and 19°C, while those from August to November and April to July were 6 and 8°C and 8 and 10°C respectively. Thus the peak leaf fall occurred during the high range of between 16 and 19°C. Therefore p eaked-leaf fall might be related to low rainfalls and high temperature ranges. It has also been shown that leaf fall and organic debris production and total litterfall were positively correlated with high ambient temperatures (P < 0.01) and negatively correlated with rainfall in other types of mixed forest (Lam & Dudgeon, 1985; Ola-Adams & Egunjobi, 1992; Tetteh, 1992).

There were highly significant differences in monthly leaf fall among spacings for the species. This was contrary to what Nwoboshi, 1970 and Ola-Adams 1992 observed in their studies. They observed no significant difference between stockings and season of fall, but the significant differences observed in this study might be due to very high densities in the various spacings. Comparable data for Gmelina elsewhere is not available except in Ghana. Thus, the total leaf litter obtained for this study was higher than the values obtained in conventional Gmelina stand at Kwadaso near Kumasi (Tetteh, 1992). This might have arisen due to the relatively high stocking densities used in the present study.

Nutrient Retranslocation

The percentage of nutrients retranslocated from senescing leaves is markedly higher than those reported for other species elsewhere. Ola-Adams & Egunjobi (1992) observed that the amounts of nutrients in different spacings were in proportion to the dry weights of the litter produced in Tectona and Terminalia in Nigeria. Others also mentioned that not all the elements taken up by the foliar components of the shoot return to the forest floor through litter fall in Tectona and Terminalia respectively (Nwoboshi, 1981b; Songwe, 1984). For example in Nigeria, it was observed that between 40% and 77% of the foliar content of N, P and K were retranslocated to other tree components prior to leaf fall while calcium and magnesium showed no retranslocation in Tectona (Nwoboshi, 1981b). Similar estimates for retranslocation of N, P and K were 43.9, 52.7 and 47.72% respectively in T. superba (Songwe, 1984). In both cases calcium and magnesium showed no retranslocation. It has been noted that retranslocation of nutrients from leaves to other parts prior to leaf fall is an adaptive nutrient conservation strategy for nutrient recycling within the trees especially when the nutrient status falls below critically low levels in the soil (Old-Adams & Egunjobi, 1992; Kadir et al., 1998).

CONCLUSION

In the present study, there was less retranslocation
of Mg from leaves to other tissues. Calcium on the
other hand was not retranslocated while N, P and
K significantly retranslocated. This shows that
retranslocation of nutrients in Gmelina is
possible and confirms the results of other studies
in which no retranslocation of Ca and S but little
Mg of Q Pinus hardwood trees were observed
(Driessche, 1984). Thus, it has been observed that
a nutrient conservation strategy like
retranslocation takes place in soils with low
nutrients (Grubb, 1989) such was observed in the
study site (Table 1). Again it can be concluded
that retranslocation of nutrient before leaf
abscission is an important pathway for nutrient
conservation (Kadir et al., 1998). Spacing and
months within the year also significantly
influenced the amount of leaf fall and quantity of
nutrients returned to the forest floor.

Therefore, the results of the present study, apart
from giving indication of pattern of leaf litterfall
and mineral contents within spacing also give
some quantitative basis and approaches for
evaluating the different management options with
regard to spacing. This could be done by
determining the possibility of sustainability of a
woodlot system on the basis of sustained yield
management

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REFERENCES

cyling of some tree species in high density short
rotation woodlot system. Ph.D. Thesis, Dept. of
Silviculture and Forest Management, Kwame
Nkrumah University of Science and Technology,
Kumasi. Pp. 211.

Association of Official Analytical Chemists
Washington D. C.

Agriculture and land use in Ghana. Oxford

Bremner, J. M. (1965) Total nitrogen. In Black,
1149-1178 Agronomy monograph 9 American
Society of Agronomy, Madison, Wisconsin.

Driessche, V. D. R. (1984) Nutrient storage,
retranslocation and relationship of stress to
nutrition. In: Nutrition of plantation forests. G.D.
Bowen and E.K.S. Nambiar. (eds.). Academic

production and decomposition in a Coastal Hill
Dipterocarp Forest. In: Tropical Rainforest
Ecology and Management. S.L. Sutton, T. C.
Whitmore and A. C. Chadwick (eds). Blackwell

Grubb, P. J. (1989) Thé role of mineral nutrients
in the tropics. A plant ecologist view. In mineral
nutrients in tropical forest and savanna

Hall, J. B. & Swaine, M. D. (1981) Geobotany 1:
Distribution and Ecology of Vascular Plants in a
tropical Rainforest vegetation of Ghana. Dr. W.

Forest Ecosystems: Principles and their
application in management and conservation. John
Wiley & Sons, New York.

Kadir, W. R., Cleemput, O. V. & Zeharah, A.
R. (1998) Nutrient retranslocations during the
early growth of two exotic plantation species. In:


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