AFRREV STECH
An International Journal of Science and Technology
Bahir Dar, Ethiopia

Vol.1 (2) April-July, 2012:15-31

ISSN 2225-8612 (Print) ISSN 2227-5444 (Online)

Aboveground Biomass and Litterfall Dynamics in Secondary Forest Regenerating from Degraded Rubber Plantation in Nigeria

Ichikogu, V. I.
$C/_O$ Professor A.O. Aweto
Department of Geography, Faculty of Social Sciences
University of Ibadan, Ibadan, Oyo State, Nigeria.
E-mail: victorichikogu@yahoo.com

Abstract

The differences in aboveground biomass, litterfall patterns and the seasonality of litterfall in three secondary forest fields aged 1, 5 and 10 years of age regenerating from degraded abandoned rubber plantation and a mature forest were studied in southern Nigeria. This is with a view to understanding the possibility of secondary forest regenerating from degraded *abandoned rubber plantation in recovering to the level of primary forest and performing the environmental functions of primary forest. Aboveground biomass and litterfall increased significantly with increasing age of secondary forest. Maximum litterfall occurred during the dry season in all the secondary forest categories and the mature forest. These suggest that if secondary forest regenerating from degraded abandoned rubber plantation is left long enough to grow fallow its aboveground biomass is capable of regenerating to the level obtainable in the mature forest. Consequently, the maintenance of this type of secondary forest in the tropical area would be a significant contribution to soil and watershed protection, mitigating climatic changes effects in the region, and minimizing biodiversity losses.*

Key words: Aboveground biomass. Litterfall, Degraded, Seasonality, Rubber plantation.

Introduction

Over much of southern Nigeria forest conversion to plantation agriculture is one of the predominant causes of deforestation. This activity has left a large portion of the forest biome disturbed and in various states of natural regeneration, stagnation or managed recovery. The primary forests were cleared and used for plantation agriculture. However, most of the plantations are now abandoned because of poor productivity, plant diseases and death of tree plants arising from inappropriate tapping or other reasons. Therefore, most of the areas that were occupied by plantations are now occupied by secondary forests in different stages of fallow. This land use change could alter the structure and function of any ecosystem, trigger off new feedbacks in terms of subsequent human use (Buol 1994) and alter the physical and nutrient status of the soil.

Although highly altered, secondary forests provide important ecosystem services such as watershed protection, sources and havens of biodiversity, erosion prevention, soil fertility recovery by improved fallows (Aweto 1978) and atmospheric carbon sinks (Fearnside and Guimaraes 1996, Silver et al 2000). However the potential of secondary forests to recover and maintain these roles is dependent on the intensity of previous land use (Uhl *et al*. 1988, Nepstand *et al*. 19990, Aide *et al*. 1995, Alves *et al* 1997), soil nutrient limitations (Nepstand et al 1996), and seed inputs and seedling establishment (Nepstand et al 1996). These impediments to vegetation growth may be more extreme in secondary forest regenerating from degraded abandoned tree plantation of rubber compared to secondary forest following shifting cultivation of annual crops or swidden fallow secondary forest.

In Nigeria, previous works on the dynamics and seasonality of litterfall in secondary forests have tended to concentrate more on secondary forests regenerating from shifting cultivation agricultural practices (Areola 1980, Adedeji 1984) and on post burn vegetation (Odiwe and Muoghalu 2003, Muoghalu *et al* 1994). Also, previous works on the changes in aboveground biomass in Nigeria and in other tropical forests (Lugo 1992, Hartermink 2001) focused on forests clearings produced by natural or logging activities with different intensities of land use and land use history. While there are plethora of studies on various aspects and various types of secondary forest, there is hardly any comprehensive study on the changes in the aboveground biomass, and the dynamics and seasonality of litterfall in secondary forest regenerating from degraded abandoned plantation of rubber (*Hevea brasiliensis)*. Consequently, our understanding of the natural regenerative ability of this secondary forest type is minimal.

The objectives of the present study were to estimate the aboveground biomass accumulation, determine the seasonality of litterfall and to compare the litterfall in secondary forests regenerating from degraded abandoned rubber plantation in secondary forests in different stages of regeneration. The findings of this study are most directly applicable to any part of the world where the fallow system of agriculture is practiced, most specifically Africa and Asia.

Study area

The study was carried out at Orogun a distance of about 50 kilometers away from Warri in Delta state Nigeria. It is located between latitude $5^{0}20^{'}$N and $5^{0}36^{'}$N and between longitude $5^{0}30^{'}$E and $6^{0}06^{'}$E. The climate of the area is warm and humid throughout the year with mean annual rainfall of about 2000 to 2500 mm with most of the rain falling between April and October. Temperatures are high throughout the year with no sharp seasonal variations and mean annual range of 2^{0}C. The natural vegetation is the tropical lowland rainforest of the moist evergreen type (Aweto 2001). The tree species occurring in the forest area include T*riplochiton scleroxylon*, *Milicia excelsa*, *Piptadeniastrum africanum, Scottelia coriaecea, Albizia adianthifolia, Terminalia superba, Musanga cecropoidis* among others.

The secondary forest found in the area can be grouped into two broad classes on the basis of the importance of woody plants in the spatial structure of the vegetation. They are as follow (1) The pseudo woody fallow and (2) The woody fallow proper. The pseudo woody fallows are young secondary forests of one to five years. Their floristic composition is dominated by a single plant species *chromolena odorata.* The woody fallows proper are secondary forests in which many perennial erect woody species such as A*ntiaris toxicaria, Tetrapleutra tetraptera, Anthonatha macrophylla, Funtumia elastica, Albizia adianthifolia, Berlinia grandiflora and Chlorophora excelsa* play an important role in the spatial structure of the vegetation. The ten year old fallow or secondary forest falls into the woody fallow category. The landscape of the study area is low-lying deltaic plain of southern Nigeria and is a featureless plain with vast expanses of almost flat surfaces, with land elevation of less than 25 meters above sea level. The soils are sandy, deeply weathered ferrallitic soils (Oxisols). They were formed from unconsolidated sediments of sandstone and have been intensely leached.

Methodology

Site selection and sampling

Abandoned farmlands are usually recultivated within 10 years in the study area hence 1, 5, and 10-year-old secondary forests were studied. In addition mature forest on well drained sites was studied to determine the extent to which 1, 5, and 10-year old secondary forests approached the mature state.

Prior to the collection of data, a field survey was conducted in the study area to identify the fallows in different stages of regeneration and a primary forest which has not be cultivated nor experienced major human or natural disturbances for study. During this field survey, the ages of the secondary forests and cultivation histories were ascertained from the local farmers and landowners, or the last person to have tapped the rubber prior to abandonment. A selection was made of secondary forests of different age after abandonment but which were subjected to the cultivation of rubber (*Hevea* brasiliensis) before they were abandoned for secondary forest. The age classification was based on when last the rubber plantation was tapped before it was finally abandoned for secondary forest to take over. The reason for the field survey is because of the non-availability of suitable air photographs to use as sampling frame for the random selection of the secondary forests for study.

Within each of the secondary forest age categories, ten sample plots of 30 metre square quadrats were delimited for investigation. Quantitative measurement on tree height, tree diameter and tree density was carried out in each of the 30 x 30 m quadrat (the values obtained for the tree density for the 30 m x 30 m quadrat was subsequently converted to density per hectare). The diameter, height, and identification to species of all trees with minimum breast height (dbh) of 2cm in each quadrat in each of the forest categories were recorded. These data served as the basis for calculations of tree density, basal area, and aboveground biomass estimates for the mature forest, and the 10-year old secondary forest, and also for the estimation of the aboveground biomass of the trees in the 1-year and 5-year old secondary forests (Brown and Lugo 1984). The biomasses of trees in each secondary forest type and the mature forest were calculated from the allometric equation for the tropical forests life zone using the allometric formula given by FAO (1989) for tropical areas as cited by Woomer (2006) as $y = \exp^{(-2.134+2.53\ \mathrm{In}D)}$, where y = aboveground biomass in kilogrammes, exp = 2.71828, and D is the measured diameter at breast height in cm. The biomass of the herbaceous plants in each secondary forest category and the mature forest was determined by the harvest method (Toky and Ramakrishnan 1983). During September and October 2010, when most species were at their peak biomass, all herbaceous plants from fifty 1 x 1 meter quadrats, selected randomly on the basis of five 1 x 1 metre quadrats from each 30 meter by 30 meter quadrat, under each forest category were clipped at ground level and were dried at 80^0C for 24 hours and weighed. The average herbaceous biomass value for 1x1 meter quadrat was converted to biomass per hectare and their values were added to those estimated for the tree biomass to obtain the estimated total biomass per hectare for each forest category.

Litterfall was collected at monthly intervals from 1 x 1metre traps of 30cm deep sides; with 1mm nylon mesh base which was able to retain all particles greater than about a 1mm and that could allow free drainage of water. Forty litter traps were randomly laid out in all the secondary forest categories on the basis of 10 litter traps in each secondary forest category to collect litterfall materials. Litterfall collection was done once every month from May

2010- April 2011. The monthly collections were oven dried at 80^0C for 24 hours and weighed, to determine the seasonal pattern of litterfall.

Statistical analysis

Analysis of variance tests were used to test whether or not there were significant differences between the secondary forests age-categories and primary forest with respect to litterfall and aboveground biomass. Where differences exist, post hoc multiple comparisons of means were carried out with the use of the Least Significant Difference (LSD) to check for statistical differences in soil parameters between pairs of secondary forest, and between secondary forests and primary forest. Student t test was used to test for significant differences between the litterfall in the wet season and the dry season.

Result

Aboveground Biomass and Litter Production

Table 1 shows that tree density, tree height, tree diameter tree basal area and aboveground biomass all increased with increasing age of the secondary forest. Tree density increased rapidly and even above the level of tree density in the mature forest by the tenth year of secondary forest regeneration from degraded abandoned rubber plantation.

The standing biomass in the successional communities and the mature forest increased significantly ($P<0.001$) with increasing age of the secondary forests reaching a maximum of 349.02 tonnes per hectare in the mature forest (tables 1 and 2). There was a pronounced difference between the mature forest and the oldest secondary forest (10-year fallow). Although the density of tree is higher in the 10-year secondary forest than the mature forest (2840 and 2168 trees per hectare respectively), the mature forest aboveground biomass is 4.72 times greater than the 10-year fallow.

This shows that compare to tree density, tree basal area and tree height are better measures of vegetation biomass.

Litterfall

Both the fall of leaf and twig litter increase with increasing age of secondary forest, but that of the former was higher in the 10-year old forest than the mature forest. The quantity of litter produced in the secondary forests reached

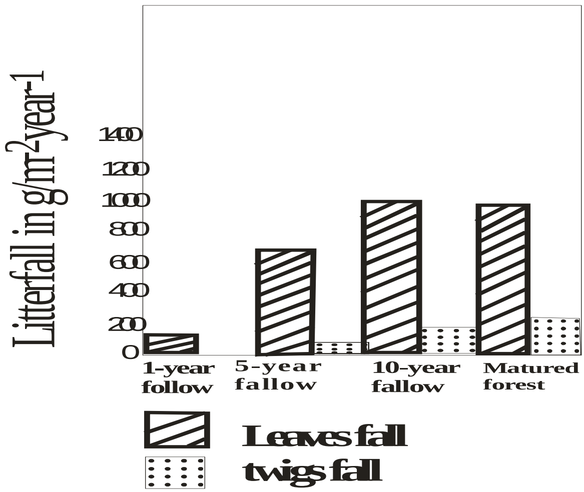
98.8% of the values of litter produced in the mature forest by the tenth year. In the 1-year fallow the litterfall was exclusively through leaf litter, there was no input from twigs (Fig. 1) Leaves accounted for 90.39%, 86.78% and 80.96% of the litter produced in the 5-year secondary forest, 10-year old secondary forest and the mature forest respectively while twigs accounted for 9.61%, 13.22% and 19.4% of the litter produced in the 5-year old secondary forest, 10-year old secondary forest and the mature forest respectively (table 1). The proportion of twigs contributed to the litterfall in the mature forest is 31.42% greater than that of the oldest fallow (10-year fallow). This implies that twigs fall contributed a significant larger proportion to the total litterfall in the mature forest than the fallow. Percentage leaf litter decreased from 100% in the 1-year old fallow to 86.78% and 80.96% in the 10-year old fallow and mature forest respectively while that of twigs increased from 0% in the 1-year fallow to 13.22% and 19.04% in the 10-year fallow and mature forest respectively (table 1 and fig.1 respectively). The total annual production of litter increased significantly with the age of the fallow. The values for the total annual litter production for the 1-year, 5-year and 10-year fallows and for the mature forests are 1114.9kgha^{-1} year^{-1}, 7146.8kgha^{-1}year^{-1}, 11184kgha^{-1}year^{-1} and 11324 kgha^{-1}year^{-1} respectively (table 1). All differences between the fallows are significant (P<0.001). Also the differences between the younger fallows (1-year and 5-year fallows) and the mature forest were significant, while the difference between the 10-year fallow and mature forest was not significant (P<0.05). *Chromolena odoratum* contributed more than 90% of the total litter in the 1-year old fallow.

Forty four percent of total annual litterfall in the mature forest occurred during the peak in March and February and 56% fell from December to April. The least quantity of litter was produced in March in the 1-year old fallow, April in the 5-year old fallow, August in the 10-year old fallow and June in the mature forest Minimum litter production coincided with the period of maximum rainfall. In the 5-year fallow about 60% of the litter produced came from C*hromolena odoratum*, while *Maesobotrya barteri, Pentaclethra macrophylla, Baphia nitida and Antiaris toxicaria* contributed the other 40% of the litter produced in the 5-year fallow. Litter from trees increased with fallow age and accounted for about 70% and 90% in the 10-year old fallow and mature forest respectively. In the 10-year fallow *Anthonata macrophylla* contributed about 58% of the litter produced while

Berlinia grandiflora, Albizia adianthifolia, Nauclea dederichii and Pentaclethra macrophylla contributed the remaining parts of the litterfall.

In the 10-year fallow *Anthonata macrophylla* contributed about 58% of the litter produced while *Berlinia grandiflora, Albizia adianthifolia, Nauclea dederichii and Pentaclethra macrophylla* contributed the remaining parts of the litterfall. In the mature forest, C*hlorophora excelsa, Astonia boonei, Maesobotrya barteri, Nauclea dederichii, Balphia nitida* and *Pentaclethra macrophylla* were the sources of litterfall.

Fig. 1 Annual litterfall (in gm^{-2} $year^{-1}$) in Suceessional communities in orogun, developed in secondary forest regenerating from degraded abandoned rubber plantation.

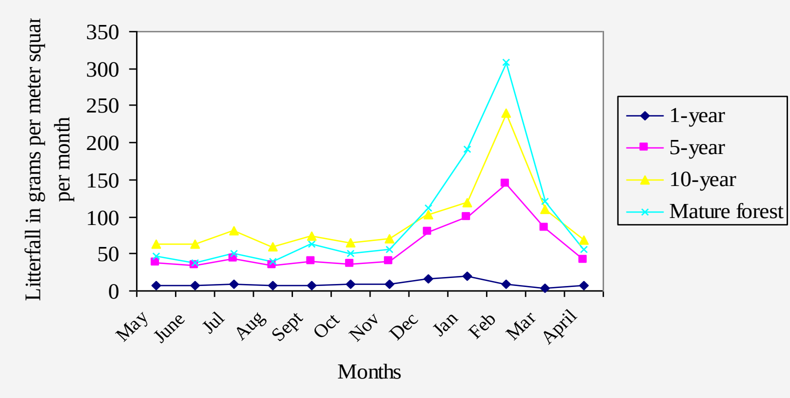


Seasonality of Litterfall

Total litterfall showed a marked seasonal peak which coincide with a peak maximum temperature and low minimum temperature (i.e. period of low humidity) due to water stress at this period. In all the fallow categories and the mature secondary forest litter production is relatively stable throughout most of the year, at 6-8.5g/m^2 /month in the 1-year fallow, 35-42.5g/m^2/month in the 5-year fallow, 65-82g/m^2/month in the 10-year fallow and 38-63.5g/m^2/month in the mature forest (between May and December).

Thirty three percent of total annual litterfall in the 1-year fallow occurred during the peak, between January and February and 54.5% fell from December to April. In the 5-year fallow, 34% of total annual litterfall occurred during the peak in January and February and 63% of litter fell from December to April. Thirty two percent of total annual litterfall in the 10-year fallow occurred during the peak in March and February while 58% fell from December to April.

Fig. 1: Seasonality of litterfall



The highest values of monthly litterfall in the 1-year, 5-year and 10-year fallows and for the mature forest were 20.42g/m^2, 143.91g/m^2, 240.48g/m^2 and 309.21g/m^2 respectively. While the corresponding values for the least monthly litterfall in each fallow categories and the mature forest were 4.28g/m^2, 34.23g/m^2, 60.26g/m^2 and 38.5g/m^2 respectively (see fig 2). This shows that the fall of litter responded to seasonal drought from December to April (i.e. litter production in the study area is strongly tied to the timing of precipitation). The total litterfall showed significant monthly variation in the mature forest and in all the secondary forests categories. In the mature forest monthly litter production increase eight fold in February at the peak of the dry season, while in the fallows it increased fourfold in the dry season showing that litter production is more erratic in the dry season in the mature forest than the 1-year, 5-year and 10-year old fallows. The differences between the litterfall in the dry and rain season were significant at P<0.001 of the 'T' distribution for all the fallow categories (table 3).

Discussion

Tree density ten years after the abandonment of degraded rubber plantation was higher than in the original forest. Higher tree density in recent fallows is expected because the open areas favour the rapid establishment of seedlings (Kennard 2002). In the following years, it is very probable that mortality rate will be higher than ingrowths, thereby decreasing density. Also, a gradual replacement of pioneers by shade-tolerant species will occur (Alves *et al*. 1997, Stenninger 2000). These probably explain the higher tree density of the 10-year old forest than the mature forest.

By the tenth year of secondary forest regeneration from degraded abandoned rubber plantation the height of the trees in the secondary forest and tree diameter have reached 73.9 and 44.65% respectively of the height and diameter respectively of trees in the primary forest. Linear increase in tree heights and tree diameter with increasing age of secondary forest in the study area is as a result of cumulative increase in the height and diameter of the trees over time. A similar trend of increase in tree height and tree diameter with increasing age of forest regeneration was reported by Marin-Spiottal *et al*. (2007) and Raphael *et al*. (2000). This indicates that secondary forest is capable of regenerating to primary forest level if left undisturbed for a long period of time.

A large increase in tree basal area with increasing age of secondary forest was noted. The values are similar to the range given for many tropical and subtropical forests [e.g. 19]. The higher tree basal area of the primary forest than the 10-year secondary forest despite the higher tree density of the latter is as a result of the higher tree diameter of the trees in the primary forest.

A large increase in the aboveground biomass with age was noted. The values of aboveground biomass estimated for secondary forests in this study fall within published range recorded for mature and secondary tropical and subtropical forests, although Bernhard-Reversat (1977) and Proctor *et al.* (1983) reported higher values for mature forests in Cot d'Voir and Sarawak. The values (t ha^{-1}) reported are: 32 for 6-year fallow in Benin, southern Nigeria (Nye and Hutton 1957); 24-42 for 2-6 year old fallow and 370 for mature for forest in Darien (Golley *et al*. 1975); 310 for a montane rain forest in New Guinea (Edwards 1977); 510 for a mature rain forest in Banco, Cote d'Ivoir (Bernhard-Reversat 1977); 210-650 for lowland rainforest Sarawak (Op cit); 5 for a 1 year old fallow in North eastern India (Toky and Ramakrishnan 1983); 23.3, 57.5, 147.6 and 147.6 for 5 year, 10 year and 20 year old fallows respectively in North eastern India (Op cit) and 229.98-307.07 (Mg ha^{-1}) in southern Brazilian Amazon (d'Oliveira *et al*. 2011)..

Guriguata and Ostertag (2001) reported that the success rate of secondary forest regeneration depends on a multitude of factors, including prior land use, available seed source, and soil fertility. Silver et al [5] found that overall aboveground biomass had significantly faster biomass accumulation during the first 20 years of succession (6.17 Mg ha^{-1} yr^{-1}) than subsequent 60 years. Nonetheless, tropical forests generally show relatively fast aboveground growth, up to 70% of mature forest height and basal area can be reached in 25 years, as observed on prior agricultural land in dry Bolivian forests (Kennard 2002).

The total litterfall in the mature forest and the 10-year old secondary forest was surprisingly similar (11.2 t $ha^{-1}year^{-1}$ in the 10-year old secondary forest and 11.47 t $ha^{-1}year^{-1}$ in the mature forest) in view of the large differences between the mature forest and 10-year old secondary forest in aboveground biomass. The near equal values of litterfall in the mature forest and the 10-year old secondary forest in this study is due to the fact that in the 10-year old secondary forest, a number of tree species are deciduous, while in the mature forest many tree species are evergreen. The fact that the total litterfall in the mature forest and the 10-year old secondary forest is nearly equal reinforces the assertion by Proctor et al (1983) that litterfall is not closely related to ecosystem nutrient status.

The highest measured litterfall value in lowland tropical forests (excluding plantations) is that for *Macrolobium* forest in Zaire where Laudelout and Meyer (1953) recorded 15.3 t $ha^{-1}year^{-1}$. Some African studies have shown higher litterfall than this study; 12.45 t $ha^{-1}year^{-1}$ was reported for a lowland secondary forests affected by fire in Ile-Ife [13]. However, these values may be misleading since the authors do not give size limits for the twigs fraction (Odiwe and Muoghalu 2003)

The strong seasonality in the amount of litterfall which is highest amount during the dry season and lowest amount during the rainy season in all the secondary forests studied in this study agrees with what was reported by other authors in West Africa tropical rain forest [Hopkins 1966, John 1973, Songwe *et al*. 1988, Muoghalu 2004, and Odiwe and Muoghalu 2003). Water stress and the deciduous habit of many tree species in these secondary forests are probably responsible for the peak litterfall during the dry season (November – March) because the humidity and rainfall at this time is low. Therefore, the high evapotranspiration exceeds rainfall leading to water stress. Many deciduous species which occur in the secondary forests shed their leaves between December and March. They bring out new leaves (flush) with the onset of rain in April and attain full canopy leafiness between June and September. Some species are leafless by December. The high twig litterfall recorded in the mature forest is due probably to the absorption of water by dead branches on the trees during the rainy season which increases their weight and their subsequent abscission and removal from crowns of trees by the force of the strong winds which accompany rains during the rainy season.

Conclusion

Wthin ten year of forest regeneration from degraded abandoned rubber plantation the aboveground biomass reached 21.2% of the level of aboveground biomass of the mature forest. This suggests that if the aboveground biomass continues accumulating at this rate it is capable of reaching the level of climax vegetation biomass within 45 years period. Consequently, the maintenance of this type of secondary forest in the tropical area would be a significant contribution to soil and watershed protection, mitigating climatic changes effects in the region, and minimizing biodiversity losses.

References

Adedeji, F.O. (1984). Nutrient cycles and successional changes following shifting cultivation practice in semi-decidious forests in Nigeria. *Forest ecology management*, 9: 87-99.

Aide, T.M.; Zimmerman, J.K.; Herrera, L.; Rosario, M. and Serrano, M. (1995). Forest recovery in abandoned tropical pastures in Puerto Rico. *Forest ecology and management*, 77: 77-86.

Alves, D.S.; Soares, J.V.; Amara, I.S.; Mello, E.M.K.; Almeida, S.A.S.; Da Silva and Silveira, A.M. (1997). Biomass of primary and secondary vegetation in Rondonia, Western Brazilian Amazon. *Global change biology*, 3: 451-461.

Areola, O. (1980). Some issues and problems in studying savanna fallows. *African Environment*, No vol. IV, 1, 51-62.

Aweto, A.O. (1978). Secondary succession and soil regeneration in a part of the forest zone of southwestern Nigeria: unpublished Ph.D thesis, Department of Geography, University of Ibadan.

Aweto, A.O. (2001). Outline geography of Urhobo land in Nigeria. http://www.waado.com.

Bernhard-Reversat, F. (1977). Recherchés sur variations stationelles des cycles biogeochimiques en foret ombrophile de Cote d'Ivoire. *Cah ORSTOM; ser. Pedol*, 15: 175-89.

Brown, S. and Lugo, A.E. (1984). Biomass of tropical forests: a new estimate based on forest volumes. *Science* 223: 1290-1293.

Buol, S.W. (1994). Environmental consequences: Soils, p. 211-229. In Meyer, W.B. and Turner B.L. (ed) changes in land use and cover: A global perspective. Cambridge University Press, U.K.

Edwards, P.J. (1977). Studies of mineral cycling in montane rainforest in Guinea II. The production and disappearance of litter. *Journal of ecology*, 65: 971-992.

Fearnside, P.M. and Guimares, W.M (1996). Amazon deforestation and global warming: Carbon stocks in vegetation replacing Brazils Amazon forest. *Forest ecology and management*, 80: 21-34.

Golley, F.B; McGinnis, J.T.; Clements, R.G.; Child, G.I. and Duever, M.J. (1975). Mineral cycling in a tropical moist forest ecosystem University of Georgia Press, Athens, Georgia.

Guriguata, R.M. and Ostertag, R. (2001). Neotropical secondary forest succession: changes in structural and functional characteristics. *Forest ecology and management*, 145: 185-206.

Hartemink, A. E., 2001: Biomass and nutrient accumulation of *Piper aduncum* and *Imperata cylindrica* fallows in the humid lowlands of Papua New Guinea. *Forest Ecology Management*, 144, 19–32.

Hopkins, B. (1966). Vegetation of the okokomeji forest reserve, Nigeria IV. The litter and soil with special reference to their seasonal changes. *Journal of ecology*, 514: 687-703.

Ichikogu, V. I. (2011a). Soil fertility rejuvenation following the abandonment of degraded rubber plantation in orogun area of southern Nigeria. *International Journal of Architecture and Built Environment*. 3 (1) 99-104.

John, D.M. (1973). Accumulation and decay of litter and net production of forest in tropical Africa. *Oikos*, 24: 430-435.

Kennard, D. K., (2002) Secondary forest succession in a tropical dry forest: Patterns of development across a 50-year chronosequence in lowland Bolivia. *J. Trop. Ecol.*, 18**,** 53–66.

Loudelout, H. and Meyer, J. (1954). Mineral element and organic material cycles in the equatorial forest of the Congo. *Occeologia planetarium*, 7: 1-21.

Lugo, A.E. (1992). Comparison of tropical tree plantations with secondary forest of similar age. *Ecological monographs*, 62: 1-42.

Marin-Spiottal, E., Ostertag, R., and Silver, W.L. (2007). Long-term patterns in tropical reforestation: plant community composition and aboveground biomass accumulation. Ecological Applications 17: 828-839.

Muoghalu, J.T.; Adeloye, O.M. and Balogun, R.T. (1994). Litter decomposition and inorganic element dynamic in a secondary rainforest at Ile-Ife, Nigeria. *African journal of ecology*, 32: 208-221.

Nepstand, D.; Uhl, C. and Serrao (1990). Chapter 14: Surmounting barriers to forest regeneration in abandoned highly degraded pastures: A case study from paragominas, Para, Brazil. Pages 215-229 in A.B. Anderson, editor. Alternatives to deforestration: Steps toward sustainable use of the Amazon rainforest. Columbia University Press, New York.

Nepstand, D.C.; Uhl, C.; Pereira, A. and Silva, J.M.C.D. (1996). A comparative study of tree establishment in abandoned pasture and mature forest of eastern Amazonia. *Oikos*, 76: 25-32.

Nye, P.H. and Hutton, R.G. (1957). Some preliminary analysis of fallows and cover crops at West African institute for oil palm research Benin. *Journal of West African institute for oil palm research*, 2: 237-243.

Odiwe, A.J. and Muoghalu, J.I. (2003). Litterfall dynamics and forest floor litter as influenced by fire in a secondary lowland rainforest in Nigeria. *Journal of tropical ecology*, 44(2): 243-251.

d'Oliveira, M.V.N. Alvarado, E.C. Santos, J.C. and Carvalho Jr. J.A. (2011). Forest regeneration and biomass production after slash and burn in a seasonally dry forest in the Southern Brazillian Amazon. *Forest Ecology and Management*, 261: 1490-1498.

Proctor, J.; Anderson, J.M.; Fogden, S.C.L. and Vallack, H.W. (1983). Ecological studies in four contrasting lowland rainforests in Gunung Mulu national park Sarawak II: Litterfall and productivity. *Journal of ecology*, 71: 735-745.

Raphael, J.M. Patrice, C. Jean, T. and Jean-Luc, C. (2000). Relationships between abiotic and biotic soil properties during fallow periods in the Sudanian zone of Senegal. *Applied Soil Ecology*, 14: 89-101.

Silver, W.L.; Ostertag, R. and Lugo, A.E. (2000). The potential for carbon sequestration through reforestration of abandoned tropical agricultural pasture lands. *Restoration ecology*, 8: 394-407.

Songwe, N.C.; Faseun, F.E. and Okali, D.U.O. (1988). Litterfall and productivity in a tropical rainforest, southern Bakundu forest, Cameroon. *Journal of tropical ecology*, 4: 25-37.

Steininger, M. K., (2000) Secondary forest structure and biomass following short and extended land-use in central and southern Amazonia. *J. Trop. Ecol*., 16**,** 689–708.

Toky, O.P. and Ramakrishnan, P.S. (1983). Secondary succession following slash and burn agriculture in north-eastern India II: Nutrient cycling. *Journal of ecology*, 71: 746-753.

Uhl, C.; Bushcbacher, R. and Serrao, E.A.S. (1988). Abandoned pastures in eastern Amazonia I. patterns of plant succession. *Journal of ecology*, 76: 663-681.

Woomer, P.L. (2006). Estimating carbon stocks in smallhold agricultural systems. http://www.formatkenya.org/ormbooks/Chapters/chapter7.htm.

Table 1: Mean Tree Density (Number of Trees DBH > 2 Cm /Ha), Tree Height (In Metres), Tree Diameter (In Cm), Tree Basal Area (In M^2ha^{-1}), Aboveground Biomass (T Ha^{-1}), Leaf Litter, Twig Litter and Total Litterfall (in kg ha^{-1}).

	AGE CATEGORIES			
Vegetation parameters	1-year old secondary forest	5-years old secondary forest	10-years old secondary forest	Primary forest
Tree density	56	1488	2840	2168
Tree height	1.74	4.18	6.44	8.77
Tree diameter	1.03	4.75	9.23	20.65
Tree basal area	0.16	2.76	18.21	72.99
Aboveground biomass	5.11	30.14	74.00	349.02
Leaf fall	1114.9 (100%)	6459.9 (90.4%	9701.5 (86.8%)	9167.9 (80.8%)
Twigs fall	-	686.9 (9.61%)	1878.5 (13.2%)	2156.1 (19.2%)
Total litterfall	1114.9	7146.8	11184	11324

Table 2: Summary Table of Results Obtained by Analysis of Variance for Vegetation Parameters

Parameter	Source of variation	Sum of squares	MSE	Calculated F	Probability of F	DF	Decision
Above ground biomass	Between samples	757179.98	252393.33		0.0001	3	Significant
	Within samples	28064.66	779.57	323.76		36	
Litterfall	Between samples	60409.35	20136.45	11.23	0.001	3	Significant
	Within samples	78892.39	1793.01			36	
Tree height	Between samples	268.15	89.37	2233.5	0.0001	3	Significant
	Within samples	1.27	0.04			36	
Basal area	Between samples	34534.02	11211.34	272.85	0.0001	3	Significant
	Within samples	1518.98087	42.19			36	
Tree density	Between samples	261.97	87.32	171.22	0.0001	3	Significant
	Within samples	18.37	0.51			36	