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DETERMINATION OF CARBON SEQUESTRATION, CARBON ESTIMATION AND STORAGE CAPACITY OF TREES IN OMO BIOSPHERE RESERVE, NIGERIA USING REMOTE SENSING AND GIS.

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Abstract

The study examined the methods applied in the estimation of forest woody biomass and its carbon content according to main tree parameters on the forest stand scale in Omo Biosphere Reserve Southwest, Nigeria and were analysed. Twenty-two (22) sample plots (30m by 30m) of tree species greater than 20cm at DBH and their heights were collected respectively. The mean carbon stock in above-ground tree biomass per unit area was estimated based on field measurements and remote sensing techniques using representative random sampling. Tree attributes were measured and converted into carbon estimates using allometric relationship and remote sensing techniques for normalized-difference vegetation index (NDVI). Techniques such as simple linear regression and correlation techniques were used to analyse the data and the results were presented in tables, charts and maps. Through the analysis of the samples of tree species, the total carbon contents of carbon in dry matter of biomass were determined for Omo Biosphere Reserve, Nigeria. The above-ground biomass was estimated at 10,412.92 metric tons/ha. Carbon-dioxide (CO_2) sequestered 8,400,800.44 tCO_2-e ha-^{1,} carbon dioxide emitted was found to be 38,215.41 tCO_2-e ha-^{1}. The regression analysis showed that CO_2 sequestered and CO_2 emitted had a correlation of determination which is R^2 0.8473 while the correlation ranged between 0.92 to 1. The price per dollar ($) of CO_2 sequestered (metric tons per hectare) revealed the total cost of $252,024,013.20. The regression analysis indicated that NDVI and AGB had a value of 0.7342. The study showed that Omo Biosphere Reserve trees stored high carbon content per tree, due to tree sizes, higher wood density and tree maturity. The study concluded that the environmental and socio-economic values of woody biomass estimation of a country's forest resources are important for strategic planning of its judicious use. It then becomes expedient to apply adaptation measure, substantial planting of trees, sustainable forest management, and urgent development of existing forest and game reserves with a view to mitigating grave environmental hazard.

Keywords: Carbon sequestration, Carbon estimation, Omo Biosphere Reserve, Remote sensing and GIS, NDVI

Introduction and background to the problem

Deforestation is considered as the most serious threat in African countries. FAO, 1999 estimate confirmed that the continent lost 10.5 per cent of its area under forest between 1980 and 1995, which was worse than that reported for the developing world as a whole. The annual rate of deforestation in 1990 and 1995 was 0.7 percent for Africa, over twice the world average of 0.3 percent. The general consensus of these documents is that monitoring of forest cover change using satellite remote sensing is practical and feasible for determining baseline deforestation rates against which future rates of change can be based, provided that adequate validation and accuracy assessments are conducted and documented. FAO's state of the world's forest (FAO, 1997a) indicates that, while the world average contribution of forestry to GDP is 2 per cent, it is 6 per cent in Africa. Furthermore, out of 24 countries in the world where forestry's contribution to GDP is 10 per cent or higher, 18 of them are in Africa. In support of REDD, the Intergovernmental Panel on Climate Change (IPCC 2006) provided guidelines to assist countries in developing carbon assessment methodologies. There is a need to first understand what forest cover (and therefore biomass) change is taking place in order to calculate baselines for any carbon credits or ecosystem services payments. It is important to provide reliable data on the spatiotemporal variation of aboveground biomass (AGB) in tropical forests.

Mapping and monitoring carbon stocks in forested regions of the world, particularly the tropics, has attracted a great deal of attention in recent years as deforestation and forest degradation account for up to 30% of anthropogenic carbon emissions, and are now included in climate change negotiations. This is true not only in terms of improving estimates of carbon stored in forests for the emerging carbon markets, by providing spatially explicit information on the location of carbon stocks, but also with respect to avoiding the ambiguities, uncertainties and outright differences among land cover type classifications. A carbon stock approach could allow countries to report at a higher IPCC (Intergovernmental Panel on Climate Change) reporting tier by providing country-specific data and advanced methods and data for land conversions, even at a Tier 3 level which is defined in the Good Practice Guidance (GPG) as including "models and inventory measurement systems tailored to address national circumstances, repeated over time, and driven by high-resolution activity data and disaggregated at sub-national to fine grid scales (GPG 3.17)". There is a need to first understand what forest cover (and therefore biomass) change is taking place in order to calculate baselines for any carbon credits or ecosystem services payments.

The results can be used as a benchmark to help quantify the success of future carbon offsetting schemes, improve protection of forest reserves and national parks through specific targeting of resources, and be used in conjunction with other socio-economic data to help monitor the success of the National Forest Programme. Currently, land use changes are estimated to cause about 70% of Nigeria GHG emissions.

Justification of the Study

To combat the growing threat of global climate change from increasing concentrations of greenhouse gases in the atmosphere, the Kyoto Protocol includes project-based mitigation efforts to achieve large-scale and cost-effective emissions reductions. Accurate estimates of terrestrial carbon storage over large areas are required to determine its role in the global carbon cycle, estimate the degree that anthropogenic disturbance (i.e., land use/land cover change) is changing that cycle, and for monitoring mitigation efforts that rely on carbon sequestration through reforestation. Remote sensing has been a key technology involved in existing efforts to monitor carbon storage and fluxes (Cohen *et al*. 1996, Running *et al*. 1999), and has been identified as a likely tool for monitoring carbon related treaties such as the Kyoto protocol (Ahern *et al*. 1998). The wise estimate of land use land cover calls for a decision support systems or tool. The appropriate of such decision support tool is the application of remote sensing, geographic information systems (GIS) and allometric methods which will have tremendous impact on carbon stock estimate.

Statement of Problem

Tropical forests play a very significant role in mitigating global climate change. They hold importance in ecosystems. Forests are estimated to sequestrate about 15% of global carbon emissions, global deforestation and forest degradation accounts for up to 20% of annual greenhouse gas emissions (Achard *et al*. 2007; Angelsen 2008). There has been significant progress on climate change mitigation options, such as the REDD-plus scheme (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries). Estimating above ground biomass (AGB) is still a challenging task in tropical and sub-tropical area which has biophysical environment (Lu, 2005). According to (Sierra, *et al.*, 2007) detailed ground-based quantifications of carbon stocks are still few.

Accurate and reliable estimation of biomass in tropical forest has been a challenging task because a large proportion of forest area is inaccessible. Lack of reliable up-to-date data has been a fundamental obstacle to understanding the scale of deforestation and forest degradation, and to monitoring the extent of forest reduction (Springate-Baginski and Wollenberg 2010). Also, (Nguyen, 2010) said lack of information about global biomass due to uncertainties in accuracy and cost is still remaining as a matter of further exploration. Tropical forests often contain 300 or more species, but research has shown that species-specific allometric relationships are not needed to generate reliable estimates of forest carbon stocks. Grouping all species together and using generalized allometric relationships, stratified by broad forest types or ecological zones, is highly effective for the tropics because DBH alone explains more than 95% of the variation in aboveground tropical forest carbon stocks, even in highly diverse regions (Brown 2002).

Scope of Study

A good estimate of carbon sequestration is essential to any project of this type. The rate of carbon sequestration in live tree biomass is computed by finding the difference between the carbon stocks of a population of trees at two different ages. Estimates of carbon stock are generally produced by first measuring the total biomass of the population using one of two approaches. The first is to estimate wood volume for each tree using a volume equation, convert wood volume to mass using an estimate of timber density, and then convert wood mass to total tree biomass using a biomass expansion factor. The other approach is to apply a regression equation that directly converts external measurements, such as stem diameter and sometimes height, to total tree biomass. Individual tree biomass values produced using either approach are summed to produce the biomass of the entire population, which is then multiplied by a standard value of carbon concentration to produce an estimate of the carbon stock. Ground-based measurements of tree diameters and height can be combined with predictive relationships to estimate forest carbon stocks. Remote-sensing instruments mounted on satellites or airplanes can estimate tree volume and other proxies that can also be converted using statistical relationships with ground-based forest carbon measurements.

Broad objective

The main objective of this research is to determine carbon sequestration, carbon estimation and storage capacity of trees in Omo Biosphere Reserve, Nigeria using Remote Sensing and GIS.

Specific objectives

The specific objectives of the study are to;

i. determine the total green weight of the tree.

ii. determine the dry weight of the tree.

iii. determine the weight of carbon in the tree.

iv. determine the weight of carbon dioxide sequestered in a year.

v. determine the weight of CO_2 sequestered in the tree per year.

vi. determine price ($) per ton of carbon-dioxide (CO_2) sequestered

vii. geospatial mapping and estimation of above ground carbon stock.

1.1. Remote Sensing, GIS and Carbon Stock

It is very pertinent and necessary to carry out carbon accounting to support the UNFCCC initiative that calls for economic incentives to accomplish reduction in the emissions from deforestation and forest degradation (REDD). To have an effective forest planning and management, the use of remote sensing and Geographic Information Systems (GIS) for mapping, monitoring, and modeling are required (World Bank, 1997). There is no practical method to directly measure all forest carbon stock, both ground-based and remote sensing measurements of forest attributes can be converted into estimates of national carbon stocks using allometric relationship. There are varieties of methods of measurement of forest and carbon, but remote sensing provides local and global estimates of carbon fluxes in forests. Allometric relationships between ground-based measurement of tree carbon stocks and its crown area with or without tree height can be applied to estimate forest carbon stocks with high certainty. This has been demonstrated to reduce costs of conducting forest inventories, particularly widely spaced and inaccessible sites (Brown *et al*. 2005) and for dense forests (Pearson *et al*, 2005b). The last 20 years mark the emergence, evolution, and proliferation of satellites designed to monitor the earth and its environment.

Materials and methodology

Spatial and statistical analysis

The spatial analyses to be performed are as follows;

a. User's defined classification of the Omo Biosphere Reserve, Nigeria.

b. Perform NDVI on 2015 images. It is expected that pixels representing vegetation will have high NDVI. Water based elements like clouds and lakes will have negative values while roads, bare soil and buildings usually have near zero values.

c. **Spatial search and query**: This enables one to probe the attribute from spatial data environment or vice versa. Query provides answers to question such as where are? What is? and when is?

d. **St**atistical analysis on images. The statistical analysis performed will include regression and coefficient of determinant as stated above.

Delineation of project boundaries

This is the first step in forest carbon measurement is the delineation of the project boundaries. Spatial boundaries of the particular area need to be clearly defined to facilitate accurate measuring, monitoring, accounting, and verification. Available natural features can be used as permanent boundary markers. These can be identified with global positioning systems (GPS). Many other tools are available for identifying and delineating project area boundaries, they are remote sensing through satellite images from optical or radar sensor systems, aerial photos, topographic maps and land records. The study area can be defined by specific boundary description using GPS-based coordinates on topographic maps or by using satellite images. GPS points are used for geo-referencing as required for increased accuracy and precision on satellite images and GIS data.

Stratification of the study area

After delineation of the project area, it is very important to collect basic information on features such as land use land cover as well as data on vegetation and topography. These data can be geo-referenced and traced on to base map. A base map specifies the details of the study area by indicating the different land use categories (forest, water bodies, agricultural lands, open land among others). Stratification of the project area is based on local site classification maps/tables, the most updated land-use/land-cover maps, satellite images, vegetation maps, landform maps as well as supplementary surveys, and the baseline land-use/land-cover is determined separately for each stratum. In order to make strata as homogenous as possible, a forest within the study area will be divided into different layers or blocks. Remote sensing software (ERDAS Imagine) will be used for land-cover classification and forest stratification.

Pilot inventory for variance estimation

There is need for preliminary inventory in order to estimate the variance of the carbon stock in each stratum and to provide a basis for calculating the number of plots required for the inventory. Twenty-two (22) plots were established in each forest block and/ stratum within the project boundary. Random selection is important in order to cover the natural variability present within the different forest blocks and or stratum. According to MacDicken, 1997, plot size is dependent on tree density.

Data collection from field work

It is not possible to measure every tree within a forest. Statistical sampling theory explains how measuring only a fraction of the trees provides a measure of the biomass that is good enough to be used in carbon accounting. Field work is required to measure DBH as it is the predictor of carbon estimation. DBH is measured from the study area which will help as ground-truth data for estimation of the biomass as well as validation of the model. Plots will be established with the help of global positioning systems (GPS). GPS will be used to navigate to the plot center. Measurement of DBH alone or in combination of height can be converted to estimate carbon stock using allometric equation. With the assigned radius the trees with diameter more than 10cm would be measured at breast height i.e. 1.3m from the ground level. All trees above or equal to 20 cm in diameter at breast height (DBH) within sample plots were measured and recorded on the data sheet.

Ground-based Forest Inventory Data

Since no satellites can directly measure forest carbon, a baseline assessment must be developed using a combination of maps that include regional forest cover and condition, with estimates of forest carbon densities from field work. Forest inventory involving forest measurements and direct estimation of aboveground biomass through destructive sampling could greatly improve the quantification of forest carbon stocks. Measurements of diameter at breast height (DBH) alone or in combination with tree height can be converted to estimates of forest carbon stocks using allometric relationships. The allometric equations statistically relate the measured forest attributes to destructive harvest measurements (e.g. Brown 1997, Chave *et al* 2005, Keller *et al* 2001). Allometric equations that relate *tree diameter at breast height* (1.3m; DBH) to other attributes such as *standing carbon stock*, *leaf area* and *basal area* are an important and often-used tool in ecological research as well as for commercial purposes. Such tools represent the primary method for estimating above-ground forest dry-matter or carbon stocks.

Regression Analysis and Validation of the Model

Regression analysis is done for determining the relationship between dependent and independent variables and works on the cause and effect relationship. Validation of the model will be carried out by comparing the amount of carbon predicted by the model and amount calculated from the field data.

Software

The software to be used are itemized below with their uses

1. ArcGIS 10.1 for GIS analysis

2. Erdas Imagine 2010 for image processing and remote sensing application

3. Landsat imageries

4. Statistical analysis

5. eCognition Developer for object based image analysis

Results

i. Aboveground biomass of Omo Biosphere Reserve, Nigeria

The total aboveground biomass of all the trees in the sampled plots revealed a sum of 10,412.92 metric tons per hectare.

ii. The total green weight of the tree.

The total green weight of the tree in the sample plots in Omo Biosphere Reserve showed the value of 5,042,918.41 metric ton per hectare.

iii. Total green weight with root included

The total green weight with root included of the tree in the sample plots in Omo Biosphere Reserve showed the value of 6,051,502.09 metric ton per hectare.

iv. The total dry weight

The total dry weight of trees in Omo Biosphere Reserve 4,387,339.01metric ton per hectare.

v. The weight of carbon in the tree

The total carbon content of the tree in the sample plots showed 2,193,669.51 metric tons per hectare.

vi. The weight of carbon dioxide sequestered

The total weight of carbon-dioxide sequestered in the sample plots showed 8,400,800.44 metric tons per hectare.

vii. The price ($) per ton of Carbon dioxide (CO_2) sequestered

The CO_2 sequestered (metric tons per hectare) of 8,400,800.44 x $30 showed the total cost of $252,024,013.20.

viii. The weight of carbon dioxide ($CO_{2)}$ emitted if forest is burnt or deforested

The total weight of carbon dioxide emitted if forest is burnt or deforested 38,215.41 metric tons per hectare.

ix. The regression analysis between carbon dioxide sequestered and emitted

The output of regression analysis between carbon dioxide sequestered and emitted is showed below as $R^2$0.8473.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.92048
R Square	0.84728
Adjusted R Square	0.84001
Standard Error	449.192
Observations	23

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	23507712	23507712	116.505	5E-10
Residual	21	4237251	201773.9		
Total	22	27744963			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	58.8737	175.5543	0.335359	0.74068	-306.21	423.959
CO_2 Seq.	0.00458	0.000424	10.79376	5E-10	0.0037	0.00546

Correlation coefficient between CO_2 sequestered and emitted

	CO_2 Sequestered	CO_2 emitted
CO_2 Sequestered	1	
CO_2 emitted	0.920477	1

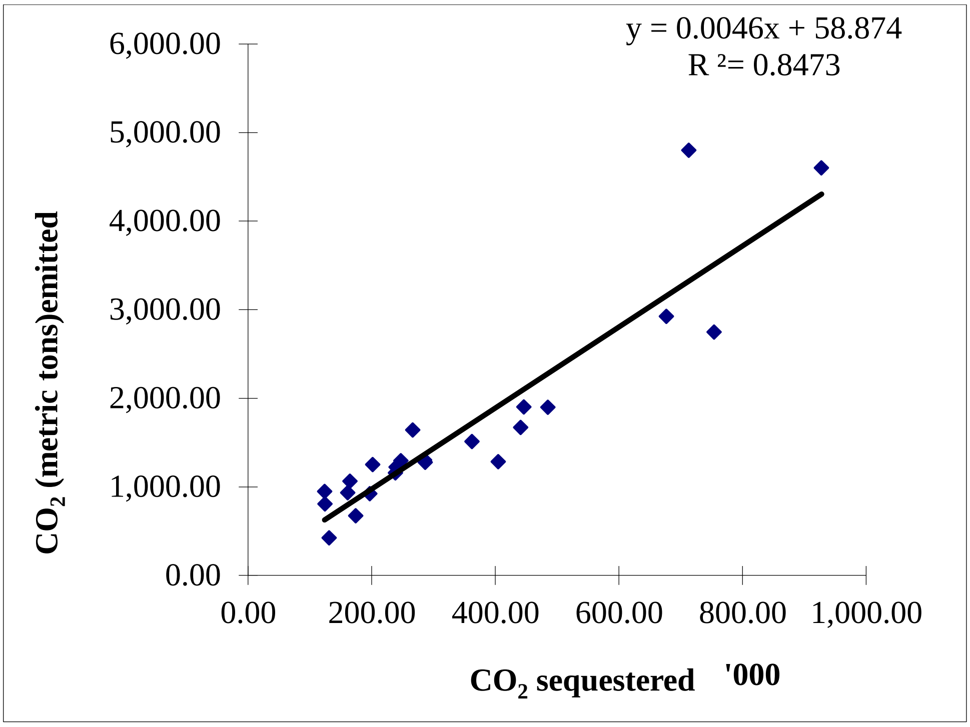

Figure 1: Carbon dioxide sequestered and emitted in metric tons per hectare

Interpretation of regression analysis of CO_2 sequestered against emitted

Carbon-dioxide sequestered revealed 58.8737 + 0.0046 CO_2 sequestered. This means that CO_2 sequestered is predicted to increase by 0.0046 metric tons, when CO_2 increases or goes up by 1 metric ton and is also 58.8737 metric tons when CO_2 is zero.

H_o: CO_2 seq. coefficient = 0

H_1: CO_2 seq. coefficient ≠ 0

5 – 10 P – value for the regression suggests significance of the regression, P – value for the carbon-dioxide sequestered coefficient shows significance of the coefficient and an evidence suggesting rejection of H_0. Evidence in this result suggests high confidence that carbon-dioxide sequestered has correlation with Carbon-dioxide emitted.

R^2 value 0.8473 suggests that Carbon-dioxide sequestered accounts for or predicts 84.73 per cent of the variation in above-ground biomass. Correlation coefficient of 0.9205 between above-ground biomass and Carbon-dioxide sequestered equally suggest high correlation between the two variables.

Geospatial Mapping and Estimation of Above-ground Carbon Stock.

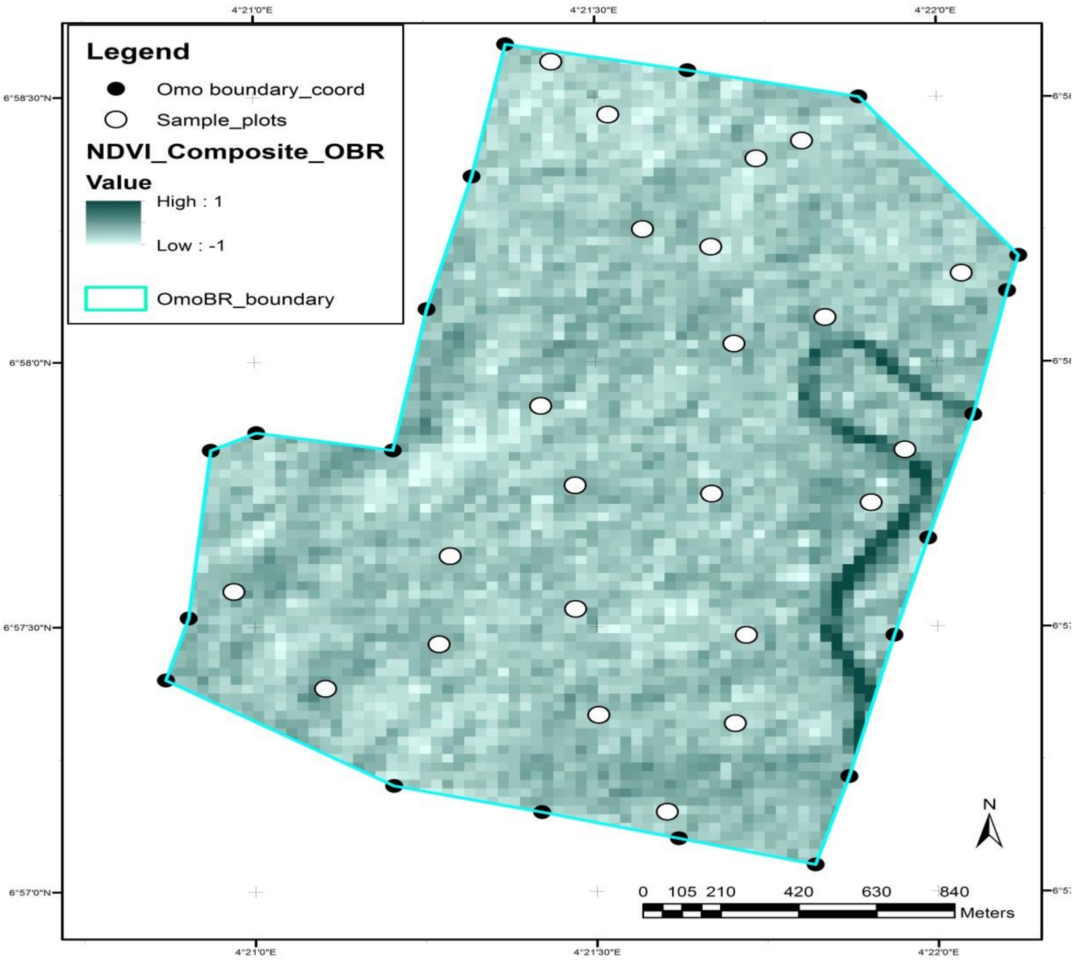

Figure 1: The Normalized-Difference Vegetation Index of Omo Biosphere Reserve, Nigeria

Discussion

Carbon-dioxide emitted if forest is burnt or deforested

The prediction that carbon-dioxide would be emitted if forest is burnt or deforested depend on the growth characteristics of the tree species, the conditions for growth, and the density of the tree's wood. The more sequestered carbon, the less carbon-dioxide would be emitted. Forest would emits 38,215.41metric tons per hectare. It is therefore concluded that high rate of carbon stock, the less carbon loss. But this would take longer time to recover.

Recommendations

For environmental and economic value of woody biomass, estimation is important to know forest biomass resources in the country and present these facts to international institutions or in treaties as needed. This estimation is very important for strategic planning of the use of renewable energy sources from woody biomass. On the other hand, estimation of the carbon content in forest woody biomass has importance in global climate mitigation policy and processes (Kyoto- and post-Kyoto period). The concept of using satellite images in the land use land cover change demonstrated the extent and status of forest.

For now, there is no country specific allometric equation has been designed for Nigeria. Having the equation in place will improve the accuracy of aboveground biomass estimation with respect to carbon estimation, monitoring, reporting and verification for REDD+ program. It is therefore pertinent to fully understand dynamic nature of carbon sequestration for natural forest and plantation. Further studies are needed to improve C accounting.

References

[1] Achard, F; DeFries, R; Eva, H; Hansen, M; Mayaux, P; Stibig, H-J (2007) Pan-tropical monitoring of deforestation. Environ. Res. Lett. 2: 045022 (11pp).

[2] Ahern, F. J., A. C. Janetos, and E. Langham. 1998. Global Observation of Forest Cover: one component of CEOS' Integrated Global Observing Strategy. Pages 1-5. *27th International Symposium on Remote Sensing of Environment*, Tromsø, Norway.

[3] Brown S, Pearson T, Slaymaker D, Ambagis S, Moore N, Novelo D and Sabido W 2005 Creating a virtual tropical forest from three-dimensional aerial imagery: application for estimating carbon stocks *Ecol. Appl.* 15 1083–95 Oecologia 145 (1): 87-99.

[4] Brown, K.: 1997, 'The Utility of Remote Sensing Technology in Monitoring Carbon Sequestration Agroforestry Projects' report for Winrock International Institute for Agricultural Development; Arlington, Virgina.

[5] Brown S and Gaston G 1995 Use of forest inventories and geographic information systems to estimate biomass density of tropical forests: applications to tropical Africa *Environ. Monit. Assess.* 38 157–68

[6] Chave, J., Andalo, C., Brown, S., Cairns, M.A., Chambers, J.Q., Eamus, D., Fölster, H., Fromard, F., Higuchi, N., Kira, T., Lescure, J.P., Nelson, B.W., Ogawa, H., Puig, H., Riéra, B. and Yamakura, T. 2005 Tree allometry and improved estimation of carbon stocks and balance in tropical forests.

[7] Cohen, W. B., M. E. Harmon, D. O. Wallin, and M. Fiorella. 1996. Two decades of carbon flux from forests of the Pacific Northwest. *Bioscience* 46: 836-844.

[8] DeFries R S, Asner G, Achard F, Justice C, Laporte N, Price K, Small C and Townshend J 2005 Monitoring tropical deforestation for emerging carbon markets *Tropical Deforestation and Climate Change* ed P Moutino and S Schwartzman (Belem: IPAM and Environmental Defense) pp 35–44

[9] Food and Agricultural Organization (FAO) of the United Nations. 1997a. *Forest Resources Assessment 1990: Survey of Tropical Forest Cover and Study of Change Processes*.

[10] FAO (Food and Agriculture Organization): 2005, *The State of the World's Forests*, FAO, Rome.

[11] IPCC (2006): Chapter 4: Forest Lands. Pp. 4.1-4.83 in Eggleston, S., Buendia, L., Miwa, K., Ngara, T., & Tanebe, K. (eds.): 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Hayama, Japan, Institute for Global Environmental Strategies (IGES).

[12] Keller M, Palace M and Hurtt G 2001 Biomass estimation in the Tapajos National Forest, Brazil: examination of sampling and allometric uncertainties *Forest Ecol. Manag.* 154 371–82

[13] MacDicken, KG (1997) a guide to monitoring carbon storage in forestry and agro-forestry projects. Arlington, USA: Winrock International

[14] Nguyen, N. T. (2010). Estimation and mapping of above ground biomass for the assessment and mapping of carbon stocks in tropical forest using SAR data: a case study in Afram Headwaters Forest, Ghana. Unpublished MSc. Thesis, ITC, Enschede

[15] Pearson T, Brown S, Petrova S, Moore N and Slaymaker D 2005b Application of multispectral three-dimensional aerial digital imagery for estimating carbon stocks in a closed tropical forest *Report to The Nature Conservancy* Winrock International.

[16] Running, S. W., D. D. Baldocchi, D. P. Turner, S. T. Gower, P. S. Bakwin, and K. A. Hibbard. 1999. A global terrestrial monitoring network integrating tower fluxes, flask sampling, ecosystem modeling and EOS data. *Remote Sensing of Environment* 70: 108-127.

[17] Sierra, C. A., del Valle, J. L., Orrego, S. A., Moreno, F.H., Harmon, M. E., Zapata, M., *et al.* (2007). Total carbon stocks in a tropical forest landscape of the Porce region, Colombia. [Article]. *Forest Ecology and Management*, 243(2-3), pp 299-309.

[18] Springate-Baginski, O; Wollenberg, E (eds.) (2010) REDD, forest governance and rural livelihoods: the emerging agenda. CIFOR, Bogor, Indonesia. (pp 173–194).