International Journal of Environmental Science: Development and Monitoring (IJESDM)
ISSN No. 2231-1289, Volume 4 No. 3 (2013)

Spatial technology based assessment of biomass and carbon stock

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ABSTRACT

Spatial technology in the form of satellite or remote sensing (RS) data, geographical information system (GIS) and global positioning system (GPS) play extremely important role in assessment of biomass and carbon stock. This paper provides procedures for assessing and estimating the carbon stock in both above ground and belowground biomass (soil and biomass). The assessment of the carbon stock in the current land-use pattern is possible to carry out. The geographic area of concern (i.e. the watershed or administrative unit) has been identified and that its boundaries have been delineated in a topographic base map or corresponding cartographic materials, and that the method attempts to make full use of existing databases and analytical systems. Climate change and high rates of global carbon emissions have focused attention on the need for high-quality monitoring systems to assess how much carbon is present in terrestrial systems and how these change over time. There is a growing body of scientific and technical information on ground-based and remote sensing methods of carbon measurement.

Keywords-spatial technology; RS; GIS; GPS; biomass; carbon stock

1. INTRODUCTION

Detailed estimations of biomass of all land cover types are necessary for carbon accounting, although reliable estimations of biomass in the literature are few. Biomass and carbon content are generally high in tropical forests, reflecting their influence on the global carbon cycle. Tropical forests also have great potential for the mitigation of CO_2through appropriate conservation and management. The biomass assessment methods described here are not restricted to forests, agriculture or pastures. They assess the present biomass regardless of cover type. Thus, they may be applied to areas where trees are a dominant part of the landscape, including closed and open forests, savannahs, plantations, gardens, live fences, etc., as well as to agricultural and pasture systems, including all kinds of crop rotations, mixes of crops, trees and pastures. The biomass of all the components of the ecosystem should be considered: the live mass aboveground and belowground of trees, shrubs, palms, saplings, etc., as well as the herbaceous layer on the forest floor, including the inert fraction in debris and litter. The greatest fraction of the total aboveground biomass in an ecosystem is represented by these components and, generally speaking, their estimation does not present many logistic problems. Biomass is defined here as the total amount of live organic matter and inert organic matter (IOM) aboveground and belowground expressed in tonnes of dry matter per unit area (individual plant, hectare, region or country). Typically, the terms of measurement are density of biomass expressed as mass per unit area, e.g. tonnes per hectare. The total biomass for a region or a country is obtained by up scaling or aggregation of the density of the biomass at the minimum area measured.

Deforestation alone is responsible for about 12% of the world's anthropogenic greenhouse gas (GHG) emissions, whereas another 6% stems from peat oxidation and fires on degraded peat land areas [1]. The combined effects of logging and forest re-growth on abandoned land are responsible for 10–25% of global human-induced emissions [2,3]. Annual emissions from deforestation in Indonesia and Brazil equal four-fifths of the annual reduction target of the Kyoto Protocol [4]. Linking deforestation with climate change as a mitigation action was one of the key decisions of the thirteenth Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change. The Bali Action Plan agreed: "Enhanced national/international action on mitigation of climate change, including, inter alia, consideration of…policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries" [5]. These actions are now referred to collectively as REDD+. Under the UNFCCC, the REDD+instrument (Reducing Emissions from Deforestation and Forest Degradation), as agreed at the COP-16 of the UNFCCC in December 2010 [6], is critical for developing countries. The systematic review is not designed to provide technical guidance, such as those outlined in the Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance and Guidelines [7,8], or to be a sourcebook of methods, such as Global Observation for Forest Cover and Land Dynamics or GOFC-GOLD [9, 10].

A key challenge for successfully implementing REDD+and similar mechanisms is the reliable estimation of biomass carbon stocks in tropical forests. Biomass consists of approximately 50% carbon [11,12]. Uncertain estimates of biomass carbon stocks of tropical forests resulting from difficult access, limited inventory and their enormous extent, [12-14], prohibit the accurate assessment of carbon emissions as much as uncertainties in deforestation rates [15]. The carbon stocks of interest are both above-ground and below-ground. Although above-ground biomass (AGB) has attracted by far the most research over the years, pools of deadwood and litter could be as large as above-ground biomass. It is essential that a variety of methods to measure deadwood and litter should be reviewed. Deadwood pools, including standing dead trees, fallen woody debris, and decaying and burned wood, are of particular interest in projecting carbon losses from decomposition. They are also often used as an indicator of carbon losses from degradation due to logging [16] or fire [17]. Data collection regarding standing dead trees frequently follow the same protocols as those for AGB inventories but ideally should also include data on levels of decay.

Woody debris is most often estimated using the line-intercept method which measures only debris which crosses a transect (e.g. [16]) or through rectangular plots wherein the dimensions of each piece of debris is measured (e.g. [18]). Although some studies have addressed the densities of woody debris of different decay classes [16,19], more regionally and biome-specific studies would help refine estimates of carbon content of this pool (e.g. [20]). A reliable estimation of AGB has to take account of spatial variability, tree and forest metrics (allometric models) and wood. Many studies have been published on AGB estimates in tropical forests around the world (e.g. [21-25]), whereas the volume of literature on below-ground biomass estimates in tropical areas is relatively small.

2. MULTIPURPOSE FIELD SURVEYS AND SAMPLING DESIGN

The sampling design for the collection of aboveground biomass data should be a multipurpose one in order to realize efficiencies in data collection and minimize costs. That is, the sites that are used to take measurements for aboveground biomass estimation should also be used for biodiversity and land degradation assessments through the observation of its indicators. The multipurpose character of the sampling design demands that it should provide data for: (i) aboveground biomass estimation: morphometric measurements of standing vegetation; stem and canopy of various strata of trees and shrubs, as well as debris, deadwood, saplings, and samples of herbs and litter fall; (ii) biodiversity assessment: plant species identification and quantification for calculation of plant diversity indices; and (iii) land degradation assessment: site measurements and observations of relevant indicators of the status of land degradation.

3. REMOTE SENSING FOR ABOVEGROUND BIOMASS ESTIMATION

Remotely sensed data are understood here as the data generated by sensors from a platform not directly touching or in close proximity to the forest biomass. Therefore, these data comprise images sensed from both aircraft and satellites. Remote-sensing imagery can be extremely useful, particularly where validated or verified with ground measurements and observations (i.e. “ground truth”). Remote-sensing images can be used in the estimation of aboveground biomass in at least three ways: (i) classification of vegetation cover and generation of a vegetation type map. This partitions the spatial variability of vegetation into relatively uniform zones or vegetation classes. These can be very useful in the identification of groups of species and in the spatial interpolation and extrapolation of biomass estimates; (ii) indirect estimation of biomass through some form of quantitative relationship (e.g. regression equations) between band ratio indices (Normalized Difference Vegetation Index or NDVI, Global vegetation Index or GVI, etc.) or other measures such as direct radiance values per pixel or digital numbers per pixel, with direct measures of biomass or with parameters related directly to biomass, e.g. leaf area index (LAI); and (iii) partitioning the spatial variability of vegetation cover into relatively uniform zones or classes, which can be used as a sampling framework for the location of ground observations and measurements. The use of band ratio indices such as the NDVI, GVI or other indices based on exploiting the discriminating power of infrared band ratios of chlorophyll activity in vegetation, requires relatively involved measurements of other morphological and physiognomic parameters of the vegetation canopy such as the LAI, and the presence of a strong relationship between the LAI and the NDVI, and the LAI and the biomass. The strength and the form of such relationships vary considerably with canopy type and structure, the state of health of the vegetation and many other environmental parameters.

4. CLASSIFICATION OF VEGETATION COVER USING MULTISPECTRAL SATELLITE IMAGERY

The procedures, techniques and algorithms for multispectral image classification are all well documented in the remote-sensing literature and are also beyond the scope of this report. In summary, the steps comprise: (a) multispectral image acquisition (usually Landsat Thematic Mapper (TM) bands 1, 2, 3, 4, 5 and 7) and image enhancement (stretching and filtering), corrections (geometric and radiometric) and geo-referencing (registration); (b) creation of false colour composite (FCC) images, typically TM3 (red), TM4 (short-wave infrared) and TM5 (near infrared); (c) selection and sampling of “training sites” on the image, inspection of “clustering” of pixels of such training sites in the feature space and selection of a classificatory algorithm for the supervised classification; and (d) supervised classification consisting of using reflectance values from “training sites” and classes assigned to them in order to expand the classification to the rest of the FCC image, through the classificatory algorithms. An optional additional step is the conversion of the resulting classified image (in raster format) to vector format (raster-to-vector conversion) in order to create a polygon map of vegetation classes. Typically, the training sites should correspond to places on the ground where the vegetation cover type has been observed, recorded and validated. The accuracy of the resulting vegetation map is a function of (i) the complexity of the mix of species in the crop, vegetation or forest cover and the complexity of the spatial variability of the cover in the area; (ii) the selection of the training sites and the degree to which they are representative of vegetation classes on the ground; and (iii) the adequacy of selection of the classificatory algorithm as a function of the nature of the clusters formed by the training sites and the types of histograms of radiance values of each image band used in the classification. The generated vegetation map should display the spatial variability of major vegetation or forest cover classes in the area of concern as classes in raster or grid-cell format, or as polygons in vector format.

5. REDD+ ACTIONS

REDD+□includes the implementation of the following mitigation actions like (a) Reducing emissions from deforestation; (b) Reducing emissions from forest degradation; (c) Conservation of forest carbon stocks; (d) Sustainable management of forest; and (e) Enhancement of forest carbon stocks. This means that, potentially, all forest resources in developing countries are subject to accountable mitigation actions. The Cancun agreement also stipulates that robust and transparent national monitoring systems of the above mitigation activities shall be developed. As a consequence, for the implementation of REDD+, it is crucial to determine the spatio-temporal variation of carbon stocks. Obtaining field measurements and developing estimation models to do so is an expensive and time-consuming task. This systematic review will compare methods of measuring carbon stocks and carbon stock changes in key carbon pools and land use categories/activities identified by the Intergovernmental Panel on Climate Change (IPCC) and the UNFCCC.

6. REMOTE SENSING BASED CLASSIFICATION AND MAPPING OF VEGETATION COVER

These techniques preceded the analysis and interpretation of satellite images. They have been standard procedures in the identification of vegetation classes and forest stands in conventional land cover mapping and forest inventory work in most countries. Therefore, this report does not describe them in detail. Together with field sampling and validation, air-photograph interpretation using photo-patterns, texture, tone and other photographic characteristics as well as the stereoscopic vision and the use of the parallax bar serves to delineate classes of crop or vegetation cover or forest stands. These boundaries of classes are later transferred to a map, creating mapping units, which in turn can be digitized into a GIS, so creating a vector polygon map. The end result of this procedure is comparable with that obtained from the interpretation and classification of satellite images. The accuracies of one or the other vary depending on the expertise of the photo-interpreter, the density of field samples used for validation and on how representative they are of the variability of vegetation classes. Both procedures, multispectral satellite image interpretation and air-photo interpretation, only lead indirectly to aboveground biomass estimation. Remote-sensing techniques are regarded here, in combination with spatial interpolation and extrapolation techniques, as mechanisms for up scaling and downscaling estimates to areas of different sizes. They also provide a useful spatial framework for field sampling. For many practical and logistical reasons related to the availability and cost of remote-sensing materials in the developing world, the emphasis in this report is on the attainment of ground measurements, which serve as the basis for validation of all other estimation procedures, including remote sensing.

7. CONCLUSIONS

Remote sensing and GIS along with GPS are essential components of spatial technology. A systematic review will compare methods of assessing carbon stocks and carbon stock changes in key land use categories, including, forest land, cropland, grassland, and wetlands, in terrestrial carbon pools that can be accounted for under the Kyoto protocol (above-ground biomass, below-ground biomass, dead wood, litter and soil carbon). Spatial technology based developing effective mitigation strategies to reduce carbon emissions and equitable adaptation strategies to cope with increasing global temperatures will rely on robust scientific information that is free from biases imposed by national and commercial interests.

8. REFERENCES

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