A REVIEW ON METHODS TO ESTIMATE BIOMASS IN NATURAL FORESTS

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ABSTRACT

Carbon subsists as carbon dioxide and represents about 0.04% in the earth's atmosphere. It has acquired a lot of consideration as a greenhouse gas, due to it has possible impact on the climate of the world. Various anthropogenic activities has increased the carbon level in the atmosphere and interrupted the carbon cycle. However, environment has it's possess system of storing and sequestering the carbon in its "sinks'' or "reservoirs". Forest plays a unique role in carbon sequestration as well as mitigating the climate change. Assessment of forest carbon stocks depends upon the assessment of forest biomass. The Intergovernmental Panel on Climate Change (IPCC) recognized total five carbon pools for the terrestrial ecosystem concerning biomass, namely the below-ground biomass, above-ground biomass, woody debris, litter and soil organic matter. The above-ground biomass comprises the major portion among the all carbon pools. The paper gives detail about the traditional methods as well as their limitations. Because of the limitations of traditional methods to measure biomass of forest, generally remote sensing has been utilized for estimation of biomass of the forest in the past decade. Geo-spatial technologies like Remote Sensing (RS) and Geographic Information Systems (GIS) provides rapid assessment of above ground biomass (AGB) and terrestrial carbon stock (CS) over large areas comparatively at a low cost and in less time. This paper, aims to summarize and review the various techniques and studies that were used to estimate the forest biomass.

Keywords: Climate change, Biomass estimation, Remote sensing, GIS, Carbon stock

INTRODUCTION

Carbon subsists in the earth's atmosphere mainly as the carbon dioxide. It represents a very less percentage of the atmosphere around 0.04% approximately. Though, it plays a vital role in sustaining life on earth, as plant produce themselves from it. The natural carbon cycle is controlled and maintained by a dynamic balance among inorganic and biological processes as the geological history of the earth. The increase in the carbon dioxide concentration in the atmosphere is mostly caused by the anthropogenic activities. The anthropogenic activities like fossil fuel burning, deforestation have contributed to a long-term increase in carbon dioxide level in the atmosphere [1].

Nature has offered us with natural carbon "sponges" or "sinks" such the oceans and the terrestrial ecosystem. Forest ecosystem is the most vital carbon sinks among the terrestrial ecosystem. Forest's plant acquires the carbon dioxide in the photosynthesis process. It is expected that about 86% of the above-ground carbon of terrestrial ecosystem and 73% of the soil carbon of the earth are accumulated in the forests [2]. The tropical forests stores up to about 46% of the terrestrial carbon and about 11.55% of the soil carbon, functioning as a carbon reservoir and acting as a constant sink of carbon in the atmosphere, so it plays a important role in the natural carbon cycle [3]. According to a study administered by Lugo and Brown [4], it had been recommended that if human activities are removed or reduced from the forests, half the "matured forests" could increase the speed of carbon sequestration.

In tropical forests, the understory plants, the biomass of living trees, woody debris, the deadwood and soil organic matters comprise the most carbon pool. Among these above stated carbon pools, the tree's above ground biomass is mainly the biggest carbon pool and it is straightly affected by forest degradation and deforestation [5]. The change in the forest biomass and the changes in forest areas due to regrowth and management greatly influence the exchange of carbon between the atmosphere and the terrestrial forest ecosystem [6]. Hence, estimating the carbon stocks of forest is especially important to evaluate the degree of carbon exchange between the atmosphere and the forest ecosystem. Estimation of the amount of carbon sequestration of the forest will give us the amount of carbon emission into the atmosphere when that forest area is degraded or deforested [5, 6].

THE CARBON SEQUESTRATION:

As per the IPCC [7], there are total five carbon pools in terrestrial ecosystem which

includes biomass, namely the below ground biomass, above ground biomass, woody debris, the dead mass of litter and soil organic matter. The plants consumes carbon dioxide during photosynthesis is relocated in different carbon pools. The major part of the carbon pool is represented by the above ground biomass of plants. It is the most visible and important carbon pool of the forest ecosystem [8]. Any land use changes like deforestation and forest degradation has a direct impact on this constituent of the carbon pool. The live roots conspires the below ground biomass which plays a vital role in the carbon cycle by storing and transferring carbon in the soil. The woody debris and dead mass of litter are not a significant carbon pool because they contribute just a little fraction of the forest carbon stocks [8]. Soil is a major source of carbon release following deforestation and soil organic matter is also a main contributor to the forest carbon stocks [9, 10], next to the above ground biomass [11].

Generally, the assessed biomass components includes the live above ground biomass which comprise of the shrubs and trees excluding the roots, above ground dead biomass like fallen branches or stem and litters, and the below ground biomass which includes the roots. The main objectives of this paper are to summarize and review the different methods and research that were carried out for the estimation of carbon stocks and above ground biomass of forests and the advantages and limitations of these different techniques.

TRADITIONAL METHODS FOR ASSESSMENT OF BIOMASS:

The accurate reporting and estimation of carbon stock (CS) and above ground biomass (AGB) of forest is an immediate necessity of international caucus e.g. the Reducing emissions from Deforestation and forest Degradation (REDD, REDD+), the Unites Nations framework convention on climate change (UNFCCC) which considers conservation and mitigation plans for sustainable forest management, estimation of greenhouse gases, carbon stock enhancement and policy development and implementation. Forest biomass can be measured through field measurement and geo spatial techniques like remote sensing and GIS [12].

Tree biomass can be calculated or assessed through direct (destructive) and indirect (nondestructive) techniques. In past days destructive way was adopted which was also called as the harvest method. According to Gibbs *et al*. [5], the destructive way was the most direct method for the biomass estimation and the carbon stocks accumulated in the forest ecosystem.

In this technique all the trees get harvested in the sample plot area and then measured their weights in the field all along with its constituents like tree branches, trunk and leaves. These parts are oven dried and then again calculated their weights. This process is used for improvement of species and location specific allometric equations for biomass assessment on large scale [13]. However, the direct methods of biomass estimation are restricted to a small area because of its destructive nature as well as the cost, time and labor involved. Moreover, the destructive methods ultimately depends on field measurements and can effect in forest damage, linked with environmental consequences [14]. The nondestructive methods include biomass estimation derived from allometric equations or geo spatial techniques which use RS and GIS based integrated models.

The Allometric equations method is founded on the principle that all components of the plant show relationship among each other. It is an indirect or non-destructive way for the biomass estimation without cut down the tree and thus widely used method. Various biometric parameters of trees such as circumference at breast height (CBH), diameter at breast height (1.37m), wood density, height, crown diameter etc. are considered for the development of an allometric equation to establish the relationship among these parameters with forest biomass. The most frequently used universal volume equations that achieved from felled plants data by using the regression equation shown in the formula given below [15]:

$$Y = aX + b \text{ (1)}$$

where, a and b are statistical constants

X= Independent variable

Y= Dependent variable

In India estimation of biomass, carbon budget and carbon stock is done by different specialists based on the growing stock (GS) volume information of forest inventories and suitable conversion factor associated with both carbon and biomass [16].

ALLOMETRY AND ALLOMETRIC EQUATIONS FOR BIOMASS ESTIMATION:

If one part is correlated to another of a tree, or a certain feature is to plant size, we can name it allometry [17], which is regularly articulated as a power relationship below [18]:

$$y = axb \text{ (2)}$$

or

$$lgy = lga + blgx \text{ (3)}$$

Where y regularly addresses a trait of plant (like metabolic rate, biomass, and so forth), x shows the size of the plant body (like width at bosom stature or potentially tallness), and a and b are coefficients.

Where y regularly addresses an attribute of plant (such as biomass, metabolic rate etc.), x represents the size of the plant (such as height, diameter at breast height etc.), and a and b are coefficients.

In botany, the allometric equation is able to be utilized to estimate biomass and further ecological factors by calculating the easily measured height and diameter at breast height. Hypothetically, tree H (height) and D (diameter at breast height) can both influence tree biomass. Hence, tree biomass can be calculated by allometric equation (Eqs. (4) and (5)), which comprises both H and D [19, 20]:

$$w = aD^b H^c \text{ or } \lg w = a' + b\lg D + c \lg H \text{ (4)}$$

$$w = a(D^2 H)^b \text{ or } \lg w = a' + b\lg(D^2 H) \text{ (5)}$$

Where H and D represent tree height (m) and diameter at breast height (cm) and a, b, a', and c are the regression coefficients.

Allometric equations were generated to avoid destruction of the forests when calculating their biomass. Generally, an allometric relationship is a statistical model to calculate the biomass of the plants using their biometrical characters (e.g., diameter at breast height (DBH), height or crown size), which are simple and easy to measure [21, 22]. The selection of robust and appropriate models, has significant influence on the accuracy of the achieved estimates [23].

GEO-SPATIAL APPROACH FOR BIOMASS ESTIMATION IN FORESTS:

One of the new approaches in biomass estimation is the integration of inferences developed from remote sensing. Remote sensing data have the stipulation of a synoptic view of the area of interest, thereby gathering the spatial variability in the attributes of interest like crown closure, tree height, etc. The spatial exposure of enormous region biomass appraises that is controlled by the limited spatial level of forest inventories may be extended through the use of remote sensing data. Carbon stock and biomass assessments resulting from the data of forest inventory generally have some attributional, spatial and temporal gaps. Remote sensing data can be utilized to fill these gaps, thus leading to evaluates closer to the real value. Remote sensing data are accessible at diverse scales, from local to global, from different sources include optical or microwave, and therefore are expected to present information which can be directly related, and in unique ways, to biomass estimation [24, 25]. Though remote sensing method cannot effectively be utilized for underground biomass, it has the capability to provide significant information about above ground biomass (AGB). A large number of studies has been carried out for

biomass estimation using remote sensing data. There are various sensors available with special characteristics of spatial, spectral and temporal resolutions utilized for biomass estimation depends upon the efficiency, availability and cost. Optical remote sensing, radio detection and ranging (RADAR) and light detection and ranging (LiDAR) sensors give the three main sources of remote sensing data for biomass estimation [26-28].

AN OVERVIEW OF BIOMASS ESTIMATION IN FOREST IN INDIA:

Tiwari and Singh [29] explained a method for biomass mapping using ground survey data (nondestructive sampling method) and black and white aerial photograph through a case study in Kumaun Himalaya. They recommended the use of universal species equations for dominant and universal interspecies equation for sub ordinate species above individual species biomass equations as there might be variation in the composition and percentage of species due to factors like aspects and slope. Even though, biomass inventories can be prepared using aerial photographs along with a least non destructive sampling, it was not possible to recognize individual sub ordinate species in the aerial photographs. The aerial photograph also does not give sufficient data to construct a generalization of the forest ecosystem in

the country, as it is very heterogeneous [30].

Many studies are also done to estimate forest carbon stocks and forest biomass using remote sensing data and GIS techniques in India [31]. Slopes (angle of geographical terrain) and aspects (direction of slope with respect to the sun) were observed to affect the estimation of biomass for dry tropical forest [32]. Ramachandran et al. [33] carried out a pilot research to estimate the carbon stocks of the natural forests in the Eastern Ghats of Tamil Nadu using IRS LISS III satellite data and GIS techniques. In one more study by Kale et al. [34] the potential of the forests in Western Ghats for carbon sequestration was calculated using ground based observation with satellite remote sensing data. For their study, they utilized the satellite data of IRS LISS III and Landsat TM. In these studies [33, 34], the mapping of forest type and digital elevation models were developed using 20 m and 15 m contours respectively. Ramachandran et al. [33] concluded by way of an emphasis on the requirement to have carbon databank for all the forests in India to learn carbon sequestration potential for enhanced management of forests. Current studies have ready conjunctive utilize of remotely sensed data and ground or field inventory data [35]. Thakur and Swamy [36] assessed

forest biomass of Barnawpara Sanctuary, Chattisgarh with the help of remote sensing and ground data. It was established that there is a strong correlation among C and N densities of forest with biomass and NDVI. As per the study of Kumar *et al*. **[35]**, the combination of forest inventory and satellite data decreases the uncertainties in above ground biomass estimation.

The woody growing stock was first assessed in India by Forest survey of India in 1995 utilizing forest's inventory data (1965-1990), forest cover data and thematic maps. This information is that the major input for the carbon stocks estimation for various institutions and scientists. Forest Survey of India done another project during 2008-10 to assess the carbon stock in forests between 1994-2004 in India by utilizing remote sensing data of sample areas and field inventory method. Sheikh *et al*. **[37]** also evaluated the carbon stock in forest biomass in India for the year 2003, 2005 and 2007 utilizing satellite data and secondary data of rising carbon stock data. As per the study, there has been a constant reduce in the carbon stock in forest biomass estimation in India since 2003, in spite of a minor increase in forest cover.

SUMMARY AND CONCLUSION

Forests are the principal carbon pool on earth. It acts as a main source and sinks of carbon in the earth. Thus, it has a potential to generate a chief component in the adaptation to climate change and mitigation of global warming. Estimation of the carbon stocks of forest will enable us to assess the level of carbon loss through deforestation or the level of carbon that a forest can accumulate when such forests are redeveloped. The principal component for the estimation of forest carbon stocks is the estimation of biomass of the forest. Even though there has been various studies carried out to assess the forest carbon stocks and the forest biomass, there is still a further requirement to develop robust methods to measure the estimates of biomass and carbon stocks of all forest components and more precisely.

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