

ESTIMATING CARBON SEQUESTRATION IN FOREST VEGETATION THROUGH SEVERAL SCIENTIFIC METHODS: A REVIEW TO FIND COMPETENT METHOD FOR INDIAN FORESTS

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ABSTRACT

Tree stores carbon from the atmosphere and deposit in all its reservoirs in the form of biomass. The amount of these carbon stored in the forest vegetation is largely depends on transfers between various forest carbon pools, natural condition of forest and catastrophes as well as on different human activities. Trees are second important sink of atmospheric carbon which stores 80% of global carbon stalks and measuring carbon sequestration in forests having global attention in recognition of the role of forests in global carbon cycle, especially in mitigating CO₂ emissions which is committed by UNFCC and Kyoto Protocol. Therefore, it is necessary to know the carbon storage capacity in different plant species in their natural habitat that can be further useful in several habitat management activities and selecting species for reforestation programme. However, estimating carbon storage in vegetation is varied largely due to ecosystem diversity and diverse scientific approaches. Such discrepancy calls for more precise evaluation of such techniques with more refined approaches. The present review provides a comparative study of several scientific techniques to estimate carbon sequestration in plants which can be helpful for future studies.

Keywords: Carbon Sequestration, Tree Biomass, Native Trees, Climate Change, Global Warming

INTRODUCTION

Forests are the major vegetation type in terrestrial ecosystems (Cao and Woodward 1998) playing a pivotal role in carbon cycle (Dixon *et al.*, 1994) with the potential to absorb and store atmospheric CO₂. Evidence of climate change linked to human-induced increase in greenhouse gases (GHG) concentrations is well-documented in international studies (IPCC 2007). Similar efforts have been made by many researchers to estimate the carbon sequestration (removal of carbon in the form of carbon dioxide from the atmosphere)

capacity in the living trees (Matthews *et al.*, 1991). This review article represents several methodologies employed by the researchers to estimate carbon sequestration in plants from different geographical areas. This comparative study may provide guidelines for several ongoing studies as well as future developments in carbon sequestration research to select appropriate methodology.

Methods Employed To Measure Stored Carbon

A survey of several techniques used to estimate carbon through published scientific literatures was conducted for further replication. Selecting the optimal technique will depend on the structure, composition and scale of the various stands (Snowdon *et al.*, 2002). Stored carbon and tree biomass can be measured by *in situ* sampling method (which can be further categorized into direct destructive biomass estimation and non-destructive indirect biomass estimation method), remote sensing method or by different models (Fig. 1).

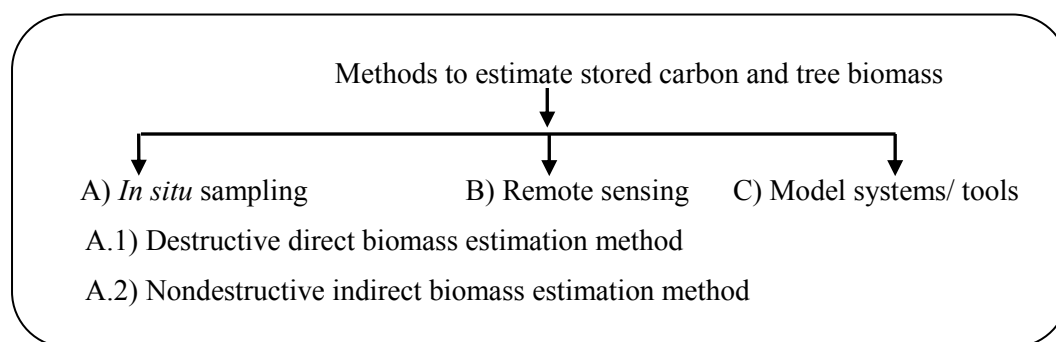


Figure 1. Different methods available for estimating stored carbon in forest vegetation

Uprooting a tree, direct destructive method is found as most precise method for quantifying biomass and for measuring stored carbon within a small unit area (Jana *et al.*, 2009). The method includes, uproot a tree, weigh the different parts of a tree and measure the biomass after drying. The biomass (dry weight) of a tree is then calculated by applying the moisture loss of the samples to the entire tree (Losi *et al.*, 2003). However, this method is referred as cost and time consuming method by many scientists (Chavan *et al.*, 2010). This method is also a destructive method as it includes uprooting entire tree and hence should not employ to measure the carbon sequestration in forested or reforested vegetation. On the other hand, measuring biomass and TOC without felling a tree using allometric (Fig. 1) or conversion factors can be relatively easy and suitable (Alves *et al.*, 1997; Brown 1997; FAO 1997, Chavan *et al.*, 2010) these approaches are considered as indirect method. In such methods, tree height and diameter are measured using some field gears like range finder or clinometer and D-tape respectively. Apart from these *in situ* methods, carbon sequestration can also be estimated by remote sensing and modeling systems (Means *et al.*, 1999).

The table below provides several most widely used methods for estimating stored carbon and biomass in forest vegetation (tree species). The table also depicts experimental protocols, their advantages, constrains and important findings along with its applicability for future studies.

Table 1. Different tools and frameworks employed for measuring carbon from forest vegetation at Indian and world level

Source/ Reference	Geographic Location	Methodology			Findings
		Method used	Advantages	Constraints	
Jana <i>et al.</i> , 2009	India, Kolkata	Tree biomass and TCT estimated using Spiegel Relascope and PerkinElmer CHNS/O Elemental Analyzer respectively.	For the first time, diurnal and especially during winter period carbon sequestration rate of plant species is undone.	With longer time scale including more number of species in different agro climatic zones more outcomes would be obtains.	Accept time and cost consume, this is most accurate method.
Chavan <i>et al.</i> , 2010	India, Maharashtra	Tree biomass and TOC measured using DBH and using allometric equation respectively.	Method is more precise, general in nature, most suitable and applicable in field.	Standard average value taken in AGC equation for wood density of tree species.	Biomass and TOC of standing tree can be measured successfully .
Negi <i>et al.</i> , 2003	India, DehraDun	TCT estimated by both ash content and regressive method.	Comparable results obtained by both methods.	Assumption factor used for carbon estimation, nevertheless, this factor is agreed by many scientists.	Relatively cost consume and extensive method
Lal and Singh 2000	India, New Delhi	Volume-based method;	Method put good result as accordance with many researchers.	For conversion of volume to biomass, available standard conversion and expansion factors used for different forest types.	Most precise method for Indian forests.
Chandran <i>et al.</i> , 2009	India, Central Western Ghats	Transect based quadrate method	Method is functional especially in surveying heterogeneous forest patches of Central Western Ghats	Assumption factor used in estimation of TCT.	Method found useful more in Indian heterogeneo us forests.

Table 1. Different tools and frameworks employed for measuring carbon from forest vegetation at Indian and world level (Contd....)

Source/ Reference	Geographic Location	Methodology			Findings
		Method used	Advantages	Constraints	
Manhas <i>et al.</i> , 2006	India	Tree Biomass and TCT measured using GS and SG of a tree.	Many researchers have been used GS based biomass and carbon for stored carbon analysis.	For stored carbon estimation in a tree, assumption factor used. Yet, it is agreed by researchers	This method is contradicted by some researchers
Dewar and Cannell 1992	UK- Queensland	Carbon-flow model/ Dewar (1991) model used.	Pools and fluxes of carbon for trees can be measured.	A negligible amount of carbon permanently lost by plants was assumed.	Outcome reveals qualitative results agreed with many scientists.
Losi <i>et al.</i> , 2003	USA	LECOCHN-600 analyzer and different drying procedures used.	Comparative result revealed assuring method.	Felling of trees, time consumption and expensive method.	This is precise and extensive method.
Heath <i>et al.</i> , 2008	USA	Component Ratio Method used.	Accordance by some researchers this is a promising method.	Some contradiction found by FIA.	Relatively reliable method.
Nowak and Crane 1998	USA	Allometric model used.	Outcome was cross- checked and verified against some test data sets and field measurements.	Almost no limitation	Relatively easy and low-cost method.

Note: SG: Specific Gravity, TCT: Total Carbon of Tree, DBH: Diameter at Breast Height, TOC: Total Organic Carbon, FIA: Forest Inventory Analysis, GS: Growing Stock

DISCUSSION AND CONCLUSION

Current rate of developmental activity is overwhelming the concentration of air pollutants as GHGs, especially CO₂. Increase in these harmful gases leads to raise the atmospheric temperature through the trapping of certain wavelengths of heat radiation in the atmosphere. To overcome this situation forests act as a potential contributor by storing atmospheric CO₂ in their different reservoir in the form of biomass (Matthews *et al.*, 2000). In terms of atmospheric carbon reduction, forest offer the double benefit of direct carbon sequestration,

storage and stability of natural ecosystem with increased recycling of nutrient along with maintenance of climatic conditions by the biogeochemical processes (Chavan *et al.*, 2010).

A key point is that apart from the origin of biomass estimators, an analysis of their applicability must be conducted (Crow and Schlaegel 1988). This analysis may be qualitative or quantitative depending on the level of accuracy desired. The more trees in an inventory the higher the precision should be bias however it cannot be corrected by sample size. Carbon projects that include a quantitative evaluation of the accuracy of biomass estimates should be noted by project verifiers so that appraisals of project value or risk may incorporate this information (Robards 2008).

The study suggests that felling trees for estimation of carbon sequestration is an accurate method; however, to avoid cutting the trees, carbon sequestration should be estimated using some non-destructive and modeling systems which is accepted by many researchers (Chavan *et al.*, 2010; Warran and Patwardhan 2001). Further, the remote measurements couple with GIS improves the accuracy of estimating carbon storage in forest vegetation (Lowson 2008).

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