Journal of
Chemical Engineering & Process Technology

Giri et al., J Chem Eng Process Technol 2014, 5:6
DOI: 10.4172/2157-7048.1000210

Research Article Open Access

Development of Biomass Expansion Factor (BEF) and Estimation of Carbon Pool in *Ailanthus excelsa Roxb* Plantation

Nishita Giri, Rajdeo Kumar*, Laxmi Rawat and Pramod Kumar

Forest Ecology and Environment Division, Forest Research Institute, Dehradun, India

Abstract

The article presents biomass and carbon stock for *Ailanthus excelsa* plantation in Dehradun Forest Division, Uttarakhand, India. Destructive sampling was used to calculate the biomass and carbon content of *A. excelsa* and Biomass Expansion Factor (BEF) was also developed for the species. The total biomass of *A. excelsa* was calculated as 126.07 t ha^{-1} with above ground biomass (AGB) 102.96 t ha^{-1} and below ground biomass (BGB) 23.11 t ha^{-1}. Carbon content in *A. excels* was 58.52 t ha^{-1} i.e. 48.3 t ha^{-1} in AGB and 10.22 t ha^{-1} in BGB and soil organic carbon (SOC) was 46.27 t ha^{-1}. Total carbon content (t ha^{-1}) in different tree components were in the order: 40.27 (bole)>10.22 (root)>5.36 (branch)>1.61 (bark)>0.73 (leaf)>0.33 (twig). BEF value calculated for the species was 1.23.

Keywords: Biomass; Carbon stock; Litter; Ailanthus excelsa roxb; Plantation ecosystem; Above ground biomass and below ground biomass

Introduction

Forests play an important role in global carbon cycling, since they are large pools of carbon as well as potential carbon sinks and sources to the atmosphere. Accurate estimation of forest biomass is required for greenhouse gas inventories and terrestrial carbon accounting. The needs for reporting carbon stocks and stock changes for the Kyoto Protocol have placed additional demands for accurate surveying methods that are verifiable, specific in time and space, and that cover large areas at acceptable cost [1-4]. Terrestrial ecosystems contain substantial carbon pools whose dynamics may impact and interact with atmospheric CO_2 concentrations [5,6], potentially influencing climatic conditions [7]. *A.excelsa* is used for agroforestry and avenue plantation and having many medicinal uses as the leaves are used for the preparation of lotions for scabies. The bark is bitter, astringent, anthelmintic and it is used in diseases like dysentery, bronchitis, asthma, dyspepsia and ear ache. The bark is also utilized in indigenous veterinary practices [8].

As young forests develop, atmospheric CO_2 is locked up into wood during growth and stored in litter layers and the soil. However, the carbon (C) sequestration potential of a forest ecosystem depends on initial soil organic carbon (SOC) content, stand growth rates, the site's biological carrying capacity, stand age, and product utilization. In particular, C sequestration and storage may be increased significantly if forests are harvested and trees are converted into wood products [9]. AGB has been given the highest importance in carbon inventory and in most mitigation projects and is the most important pool for afforestation and reforestation CDM projects under the Kyoto Protocol as well as any inventory or mitigation project related to forest lands, agroforestry and shelterbelts in croplands, while in estimating total biomass, BGB showed an important carbon pool for many vegetation types and land-use systems and accounts for about 20% [10] to 26% [11] of the total biomass. Biomass expansion factors (BEFs) applicable to stand level inventory data can be developed and tested with the help of representative volume and biomass equations [12].

The article presents stand level or ecosystem level estimates of biomass by component. This is the first report of carbon stock / carbon pool estimation in AGB, BGB of *A. excelsa* species, as well as soil organic carbon (SOC) at ecosystem level in India along with development of BEF.

Material and Methods

Study area

The study was conducted in a 28 year old *A.excelsa* plantation in Jakhan block, Barkot Range of Dehradun Forest Division, Uttarakhand, India (Map 1), nearly 25 km east of Haridwar and 30 km South east side of Dehradun city. The area lies in the subtropical region at an altitude of 449 m mean sea level (msl) with 3004'37.2"N latitude and 78°12'11.1"E longitudes. The maximum, minimum and mean temperatures of the area (1980-2010) were 28.11°C, 13.52°C and 20.32°C, respectively. The mean annual rainfall during this period was 1901.03 mm when averaging monthly and approximately 80% of the rainfall occurred during the South-west monsoon period (June to September) (Figure 1).

Soil analysis

Texture: It is the proportion of particle size distribution (soil texture) into classified grades expressed as percentage of sand, silt and clay. After air drying of samples, big stones were removed and the soil was passed through 2 mm sieve. Part of the soil samples having particle size less than 2 mm were subjected for texture analysis by Hydrometric method [13] and percentage of different fractions namely: sand, silt and clay was estimated in each sample and textural class was determined using the Triangular diagram by U.S.D.A [13].

Soil moisture: Soil moisture percentage (%) was measured by means of moisture meter.

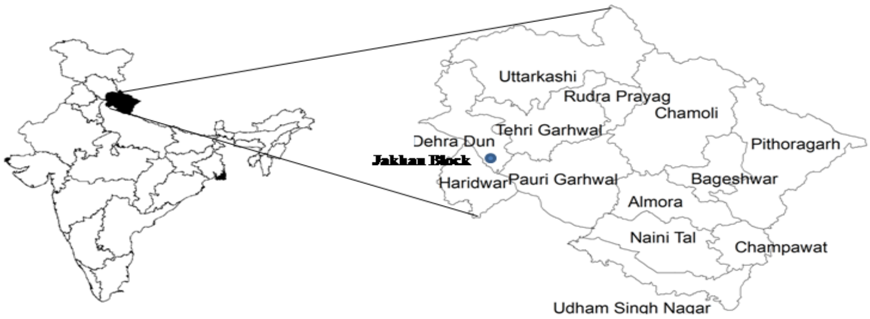
Soil bulk density: A metal core cylinder of known weight and volume was used to determine the soil bulk density [14]. Soil bulk density was determined by the following expression:

***Corresponding author:** Rajdeo Kumar, Forest Ecology and Environment Division, Forest Research Institute, Dehradun-248006 (Uttarakhand), India, Tel: +91-8591473231; E-mail: rajdeo.kumar@rediffmail.com

Received July 25, 2014; **Accepted** September 22, 2014; **Published** September 25, 2014

Citation: Giri N, Kumar R, Rawat L, Kumar P (2014) Development of Biomass Expansion Factor (BEF) and Estimation of Carbon Pool in *Ailanthus excelsa Roxb* Plantation. J Chem Eng Process Technol 5: 210. doi: 10.4172/2157-7048.1000210

Citation: Giri N, Kumar R, Rawat L, Kumar P (2014) Development of Biomass Expansion Factor (BEF) and Estimation of Carbon Pool in *Ailanthus excelsa Roxb* Plantation. J Chem Eng Process Technol 5: 210. doi: 10.4172/2157-7048.1000210



Map 1: Study site.

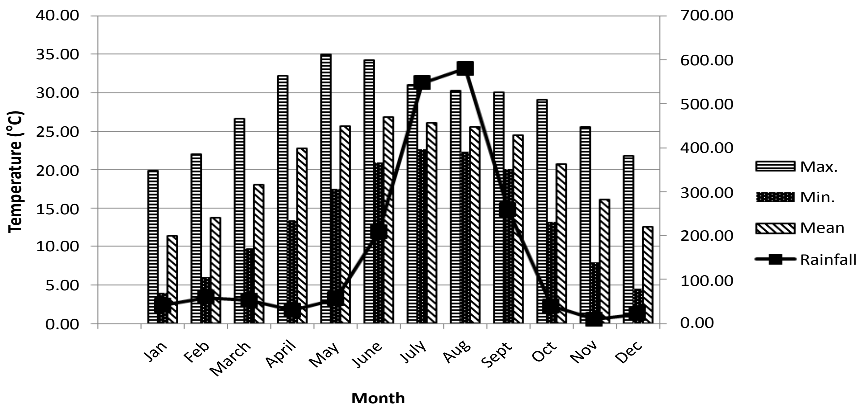


Figure 1: Ombrothermic graph of rainfall, mean, maximum and minimum temperature for one year (2010).

Bulk density (g cm^3) = (W1-W2)/V

where,

W1=weight of cylinder + weight of soil

W2=weight of empty cylinder

V=volume of cylinder

Organic Carbon (OC): The organic carbon was determined as per by Walkey and Black (1934) [15] method.

Biomass estimation of *Ailanthus excelsa*

The stratified tree technique method of Art and Marks (1971) [16] was used to harvest the sample trees. Temporary sample plots (30 m × 30 m) were laid out in the plantation and the diameter at breast height (DBH at 1.3 m) of all the standing trees were recorded within the sample plots. The DBH range was divided into five different diameter classes i.e, 10 to 20 cm, 20 to 30 cm, 30 to 40 cm, 40 to 50 cm and 50 to 60 cm from which 2 trees were harvested from 10 to 20 cm diameter class, 3 trees from 20 to 30 cm, 2 trees from 30 to 40 cm, 1 from 40 to 50 cm and 1 from 50 to 60 cm and in this way 9 representative sample trees were selected for the study.

The tree components (leaves, twigs, branches, bark, bole and roots) were separated immediately after felling and their fresh weights recorded. Samples of all tree components (100 g of each component) were selected for oven dry weight estimation and chemical analysis for C content. The bole of each sample trees was cut into 2 m long sections (billets) for convenience of weighing.

Calculation of biomass by using stand volume and Biomass Expansion Factor (BEF)

Biomass could be calculated from the stand volume per hectare by first estimating the biomass of the inventoried volume and then expanding this value to take into account the biomass of the other aboveground components, using a biomass expansion factor (BEF) defined as "the ratio of aboveground oven-dry biomass of trees to oven-dry biomass of inventoried volume" [17].

BEF was calculated as:

$$BEF = \frac{W_{aboveground}}{W_{bole}}$$

where, BEF = biomass expansion factor (dimensionless);

W_{crown} = tree crown dry weight (kg), composed of foliage, thick and thin branches;

W_{bole} = tree bole dry weight (kg); and

$W_{aboveground} = W_{crown} + W_{bole}$ (kg)

When BGB is considered in the clean development mechanism (CDM) project Root-to-shoot ratio (R) also should be taken into account and multiplied with the AGB to obtain the total BGB [18,19]. Calculation of R involves simply dividing the root biomass by the corresponding aboveground biomass as follows:

$$R = \frac{W_{root}}{W_{aboveground}}$$

S. No.	*A. excelsa* plantation	Moisture (%)	BD (g cm^{-3})	Texture (Sandy loam)		
				Sand (%)	Silt (%)	Clay (%)
1	0-30 cm	5.990 ± 0.198	1.223 ± 0.004	51.23 ± 0.470	26.83 ± 0.536	21.93 ± 0.133
2	30-60 cm	7.075 ± 0.363	1.267 ± 0.003	51.67 ± 0.636	25.80 ± 0.851	22.53 ± 0.606
3	60-90 cm	8.848 ± 0.203	1.283 ± 0.003	52.80 ± 0.208	25.37 ± 1.538	22.50 ± 0.589

Table 1: Moisture, Bulk density and Texture of soil at different depths under *A. excelsa* plantation.

where, R=root-to-shoot ratio (dimensionless); and

W_{root}=tree root dry weight (kg)

Biomass of the inventoried volume was calculated by multiplying the volume per hectare by the wood density defined as the oven-dry mass per unit of green volume and then multiplied by the BEF in order to include leaves, twigs, and branches, commonly not measured by the forest inventories. Wood density was 356 kg m^{-3} for *A. excelsa* [20].

Results and Discussion

Physical attributes of soil

Soil texture was observed to be sandy loam in nature, soil moisture was higher (8.848%) in the deepest layer that is, 60 to 90 cm depth, lower (5.990%) in uppermost layer that is, 0 to 30 cm depth. The trend of bulk density in soil depths was in the order 60 to 90 cm > 30 to 60 cm > 0 to 30 cm (Table 1).

Biomass of *A. excelsa* species

The variation in diameter (15.5-55.09 cm) and height (8.85-20.2 m) of the trees had direct effect on their biomass and the total biomass ranged from 75.04 kg tree^{-1} to 759.56 kg tree^{-1}. The variations in other tree components were: bole 40.21 kg to 551.48 kg, leaf 0.32 kg to 12.71 kg, twig 0.43 kg to 5.10 kg, branch 6.71 kg to 52.63 kg, barks 5.84 kg to 18.28 kg and root 21.27 kg to 119.36 kg among all sample trees. The total biomass of *A. excelsa* trees was estimated as 126.07 t ha^{-1}, of which the AGB comprised 102.96 t ha^{-1} and the BGB comprised 23.11 t ha^{-1}. The percentage contribution to the total biomass varied among dbh classes: 10 to 20 cm (4.52%), 21 to 30 cm (17.93%), 31 to 40 cm (27.98%), 41 to 50 cm (26.79%) and 51 to 60 cm (22.76%).

Total carbon content in *A. excelsa* tree species

Total carbon content (t ha^{-1}) in different tree components were in the order: 40.27 (bole) >10.22 (root) > 5.36 (branch)>1.61 (bark)>0.73 (leaf)>0.33 (twig). On unit area basis the amounts of C content accumulated in total biomass of *A. excelsa* trees was 58.52 t ha^{-1}.

Soil Organic Carbon (SOC)

Soil Organic Carbon was estimated as 46.27 t ha^{-1}.

In *A. excelsa* plantation ecosystem, total biomass estimated was 134.05 t ha^{-1}. Higher value of biomass was observed in bole (66.94%) followed by root (18.33%), branch (9.07%), bark (3.36%), leaves (1.59%) and twig (0.71%). *A. excelsa* tree species contribution in AGB was 102.96 t ha^{-1} and BGB estimation by the same species was 23.11 t ha^{-1}. Pande et al. [21] have also estimated biomass of *A. excelsa* at different ages in Uttar Pradesh and considered the percentage contribution of components plant parts to AGB and showed bole contributed more than 50% followed by bark, 19.9% to 23.3%, branches 9.68% to 14.5% and contribution by root was 18.1% to 25%, the contribution of different tree components of the present study was also similar to the case of Pande et al. [21] as 66.94% contributed by bole, 9.07% by branch and 18.33% by root. The per cent contribution of AGB in the present study calculated as 81.67%. Some other studies conducted by Nascimento and Laurance [22] and Henry et al. [23] have also reported over story biomass contribution of 81.9 and 81%, respectively, but the percent value is low as compared to the report of Clark and Clark (2000) [24], who have reported 92.7 to 94% contribution of over story biomass/AGB.

In present study of *A.excelsa* plantation showed maximum concentration of carbon in the bole component (47.2%) followed by other tree components and minimum concentration in the twig (36.08%). Similar trend has been reported by Kraenzel et al. [25] and Ganeshaiya et al. [26] in teak plantations.

Biomass estimation by using Biomass Expansion Factor (BEF) values

Total biomass calculated from the BEF value worked out in the present study by using following formula:

$$BEF = \frac{W_{aboveground}}{W_{bole}}$$

$$= \frac{2452.35\,kg}{1996.11\,kg}$$

$$= 1.23$$

By multiplying biomass of merchantable wood with the BEF value of *A. excelsa* trees, the biomass was estimated as:

Total AGB = Merchantable wood biomass × BEF

= 189.12 m^3 ha^{-1} (volume) × 0.356 t m^{-3} (wood density of *A. excelsa*) × 1.23

= 82.81 t ha^{-1}

Root biomass (BGB) was estimated by using root shoot ratio (R) of the felled trees and calculated as:

$$R = \frac{\text{Root biomass of felled tress}}{\text{Shoot biomass of felled tress}}$$

$$R = \frac{557.71\,kg}{2452.09\,kg}$$

$$= 0.23$$

Root biomass = Total aboveground trees biomass × R: S

= 82.81 t ha^{-1} × 0.23

= 19.05 t ha^{-1}

The total trees biomass (AGB+BGB) thus estimated to be 101.86 t ha^{-1}, which showed 19.20% underestimation with the actual biomass i.e. (126.07 t ha^{-1}) and total C content estimation was 50.93 t ha^{-1}.

Soares and Tome [27] have found analogous trends and their study on effectiveness of BEF it has been concluded that estimates of total stand biomass (aboveground and root biomass) should be derived from allometric equations and if an expansion factor is used then agedependent BEFs are recommended. They also stated that the use of a constant BEF should be avoided because it yields inaccurate estimations.

Conclusion

The provision in the small scale modalities and procedures for land-based CDM projects adopts the approach of producing biomass through the involvement of low income communities with the underlying objective that financial and environmental benefits should accrue to the communities. Thus, substituting biomass for fossil fuels by establishing bioenergy type plantations within the framework of CDM has clear advantages over using it solely as a means to sequester carbon. It has been shown that India is capable of producing biomass sustainably [28].

Carbon sequestration can be achieved effectively through forest management and conservation. If one compares global warming to a fever of the planet, then forest does not only function as a potential remedy, but their destruction also contributes to further illness [29]. Needless to say those forests/plantations are known to bring about changes in edaphic, micro-climatic, floral, faunal and other components of the eco-system through bio-recycling of mineral elements, environmental modifications (including thermal and moisture regime) and changes in floral and faunal composition etc. [30].

Carbon sequestration rates and biomass a stock varies in time (temporal) and space (spatial). A young forest would sequester more carbon than an old forest. Similarly, forests associated with better quality of soils would yield higher carbon sequestration rates. Allocation to different components of trees (bole, branch, twig, leaf, stump root, lateral roots and fine roots) is the area which is less studied and requires a better understanding in the climate change scenario and for the development of BEFs.

Acknowledgment

Authors are thankful to the Director FRI for his kind permission to publish this research articles and Uttarakhand Forest Department for logistical and financial support for conducting the study. We also acknowledged the help of Mr. Rajendra kumar for providing all necessary chemicals, reagents etc.

References

1. IPCC (2003) Good practice guidance for land use, land-use change and forestry. Hayama, Japan: IPCC National Greenhouse Gas Inventories Programme 295.
2. Krankina ON, Harmon ME, Cohen WB, Oetter DR, Zyrina O, et al. (2004) Carbon stores, sinks, and sources in forests of Northwestern Russia: Can we reconcile forest inventories with remote sensing results? Climatic Change 67: 257-272.
3. PatenaudeG L, Milne R, Dawson TP (2005) Synthesis of remote sensing approaches for forest carbon estimation: Reporting to the Kyoto Protocol. Environmental Science and Policy 8: 161-178.
4. UNFCCC (1997) Kyoto Protocol.
5. Schimel DS (1995) Terrestrial biogeochemical cycles: global estimates with remote sensing. Remote Sensing of Environment. For Ecol Manage 51: 49-56.
6. Steffen W, Noble I, Canadell J, Apps M, Schulze ED, et al. (1998) The terrestrial carbon cycle: Implications for the Kyoto Protocol. Science 280: 1393-1394.
7. Solomon S, Qin D, Manning M, Chen Z, Marquis M, et al. (2007) IPCC Fourth Assessment Report: Climate Change: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Cambridge, UK and New York.
8. Indian Council of Forestry Research and Education, Dehradun (ICFRE) (2004) Ardu (Ailanthus excelsa) 16.
9. Skog K, Nicholson G (1998) Carbon cycling through wood products: the role of wood and paper products in carbon sequestration. Forest Products Journal 48: 75-83.
10. Santantonio D, Hermann RK, Overton WS (1977) Root biomass studies in forest ecosystems. Pedobiologia 17: 1-31.
11. Cairns MA, Brown S, Helmer EH, Baumgardner GA (1997) Root biomass allocation in the world's upland forests. Oecologia 111: 1-11.
12. Lehtonen A, Makipaa R, Heikkinen J, Sievanen R, Liski J (2004) Biomass expansion factors (BEF's) for Scots pine, Norway spruce and birch according to stand age for boreal forests. For Ecol Manage 188: 211-224.
13. Black CA (1965) Methods of soil analysis. American Society of Agronomy, Inc. Publisher. Madison, Wisconsin.
14. Wilde SA, Corey RB, Iyer JG, Voigt GK (1985) Soil and plant analysis for tree culture. Oxford and IBH publishing company, New Delhi.
15. Walkley A, Black A (1934) An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil science 37: 29-38.
16. Art HW, Marks PL (1971) A summary table of biomass and net annual primary production in forest ecosystems of the world. IUFRO Meeting, University Maine Press, Orono: 1-32.
17. FAO (1997) Estimating biomass and biomass change of tropical forests- a primer. FAO Forest Paper No. 134, Rome.
18. Sanquetta CR, Corte AP, da Silva F (2011) Biomass expansion factor and root-to-shoot ratio for Pinus in Brazil. Carbon Balance Manag 6: 6.
19. Paladini E, Vuleti D, Martini I, Marjanovi H, Indir K, et al. (2009) Forest Biomass and sequestered carbon estimation according to main tree components. Period Boil 111: 459-466.
20. FRI (1985) Reprinted from the journal of timber development association of India. J Timb Dev Assoc (India) 3: 3.
21. Pande MC, Tandon VN, Negi M (1988) Biomass production in plantation ecosystem of Ailanthus excelsa at 5 different ages in Uttar Pradesh. Indian Forester 114: 362-371.
22. Nascimento HEM, Laurance WF (2002) Total aboveground biomass in central Amazonian rainforests: a landscape-scale study. For Ecol Manage 168: 311-321.
23. Henry M, Tittonell P, Manlay RJ, Bernoux M, Albrecht A, et al. (2009) Biodiversity, carbon stocks and sequestration potential in aboveground biomass in smallholder farming systems of western Kenya. Agriculture Ecosystems and Environment 129: 238-252.
24. Clark DB, Clark DA (2000) Landscape-scale variation in forest structure and biomass in a tropical rain forest. For Ecol Manage 137: 185-198.
25. Kraenzel M, Castillo A, Moore T, Potvin C (2003) Carbon storage of harvest-age teak (Tectonagrandis) plantations, Panama. For Ecol Manage 173: 213-225.
26. Ganeshaiah KN, Barve N, Nath N, Chandrashekhara K, Swamy M, et al. (2003) Carbon allocation in different components of some tree species of India: A new approach for carbon estimation. Curr Sci 85: 11.
27. Soares P, Tome M (2004) Analysis of the effectiveness of biomass expansion factors to estimate stand biomass. Proceedings of the International Conference on Modeling Forest Production, 19-22 April, Austria 368-374.
28. Rawat VRS, Kishwan J (2008) Forest conservation-based climate change-mitigation approach for India. International Forestry Review 10: 269-280.
29. Schoene D, Netto M (2005) The Kyoto protocol: What does it mean for forests and forestry. Unasylva 222 56: 3-11.
30. Shukla PK (2009) Nutrient dynamics of Teak plantations and their impact on soil productivity- A case study from India. XIII World Forestry Congress Buenos Aires, Argentina.