Comparative study on estimation of carbon content in different parts of selected bamboo species

ABSTRACT

Bamboos are a unique species in terms of their ecological impacts as well as their social and economic role in the livelihoods of people living in their vicinity. It has attracted the attention of researchers worldwide owing to its carbon sequestration ability and the potential of various bamboo species in this changing environment. In this research the biomass carbon storage of bamboo components were analyzed to estimate their respective carbon content in as well as in different components like culm, rhizome, leaves etc. *Dendrocalamus asper* stands out as the bamboo species which sequestered the maximum carbon (culm> rhizome> leaf) primarily due to its vast biomass content. The carbon content of *D. asper* was 87.52 tonnes of carbon per hectare. This was followed by *B. balcooa* with carbon content of 56.48 t C ha^{-1} with the least carbon content in *B. vulgaris i.e.*, 33.92 t C ha^{-1}. It points to the tremendous potential of bamboo in sequestering carbon but more research is desired to arrive at concrete results. Bamboo species have an inherent ability to grow in degraded lands which gives an additional advantage in promoting bamboo plantations as envisaged by National Bamboo Mission.

Keywords: Bamboo, carbon sequestration, Dendrocalamus asper, Biomass

INTRODUCTION

Carbon restoration is a unique process of capturing and storing carbon dioxide from surrounding in the atmosphere. It is one way to reduce the amount of carbon dioxide in the atmosphere with the aim of reducing global climate change (Dewar, 1990). Trees and other vegetation absorb carbon dioxide from the atmosphere, furthering about a third of the world's emissions (Patricio and Dumago, 2014). That we both maintain an existing sink and improve their ability to absorb more carbon. Net world carbon dioxide (CO_2) emissions rose to 31.10 billion tons in 2010 (Sohel *et al.* 2015). Given that the increase in atmospheric concentration of CO_2 is considered by many to create dangerous climate change there is probably an urgent need to create mechanisms that can safely reduce and eliminate carbon emissions. At present, carbon retrieval is highly dependent on existing forests or hardwood forests that are widely described as 'woody plants' (Kaminski *et al.* 2016). Globally, the total amount of carbon in the soil, vegetation, and detritus is about 2,200 gigatons (1 gigaton = 1 billion tons), and it is estimated that the amount of carbon sequestered by the earth's natural environment is about 2.6 gigatons (Selin and Noelle Eckley, 2019). The earth is poised to break the global warming of 1.5 degrees Celsius between 2030 and 2052 if it continues at current emissions levels, reveals the IPCC Special Report with global warming effects of 1.5 °C. Currently, the earth's temperature of 1.2 °C compared to pre-industrial standards. A special report, commissioned to specifically examine the scientific feasibility of the 1.5 °C goal set out in the Paris Agreement, suggests a further deterioration of extreme weather conditions as temperatures rise (Wu *et al*., 2014). Bamboo is a diverse group of evergreen flowering plants in the Bambusoideae sub family of the Poaceae family. Globally natural bamboo forests are found in tropical Asian countries between 15 N and 25 N regions as shown below (Scurlock *et al.* 2000). The natural habitat of these rhizomes is tropical and non-invasive (Zhou *and* Jiang 2004). In India, natural bamboo growth is more prevalent in the whole country except in the Kashmir region. According to (ISFR, 2019) India has about 125 indigenous species and 11 rare species of bamboo within 23 generations has around 125 indigenous and 11 exotic species of bamboo within 23 genera.

The main species include Arundinaria, *Bambusa*, *Dendrocalamus* (Wang *et al.* 2010). In bamboo, as in other grasses, the internodal regions of the stem tend to have a spine and short bundles of blood vessels are scattered throughout the stem instead of the cylindrical arrangement (David *et al.* 1983). Lack of second-growth wood causes monocot stems, including palms and large bamboo, to be column rather than touch (Wilson *et al.* 1966). Bamboo includes some of the world's fastest growing plants (Farrelly and David 1984), thanks to a unique rhizome-dependent system. Some bamboo species grow by 910mm within a day at a rate of about 40mm per hour or 1mm at 90sec (world record Guinness, 2014). Bamboo is of great economic and cultural significance in South Asia where it is widely available, in Southeast Asia and East Asia, used for construction materials, a food source, and as a raw material (INBAR, 2009). Bamboo is similar to wood, a combination of high-strength natural materials and the weight of useful structures (Lakkad *et al.* 1981). The strength of bamboo and weight is similar to that of wood, and its strength is also similar to that of solid wood or solid wood (Kaminski *et al.* 2016). However, bamboo as a carbon sink has not been fully analyzed and some researchers doubt how attractive it can be (Liese, 2009). Bamboo (experimental *Bambusa vulgaris* species) is a CO_2 net sender after a long-term study of a full day in eight bamboo lengths, thus acting as a carbon source while being a carbon sink. (Bose, 2019) wrote in his article in India Climate Dialogue that Bamboos are fastest growing plant, which can grow at the rate of up to 1.2 meters per day. Due to this, it may takes only three years to establish mature groves and the result will get is that, bamboos are effective carbon dioxide absorbers from atmosphere, and not only above ground carbon (AGC), but also below ground carbon (BGC) is stored in roots, and rhizomes of bamboo. Efforts that are studied the role that plants play in climate change mitigation is increasing day by day. Most researchers have focus on the promise of large, leafy trees. The bigger the plant, the more carbon dioxide is suggested by it. Surprisingly, bamboo has come up as a grassy climate change warrior, which grown as a low-cost sustainable, as well as household-level commercial plantation but, can also be introduced, adopted and scaled-up to secure water catchments and prevent soil erosion. It also has the potential to generate employment and high income, while at the same time significantly reducing greenhouse gas emissions. There is need to advice different ways to absorb excess greenhouse gases from the atmosphere.

Material and method

Study Area

The study was conducted in Forest Research Institute, Dehradun, Uttrakhand. It is located between 77° 52' 12" E, and 30° 20' 40" N at an altitude of 640.08 amsl. It is spread over 450 hectares in the outer Himalayas in its backdrop, which is known as the oldest institute for forestry research in entire subcontinent. FRI is located in sylvan surroundings of doon valley, the campus area of FRI is called as New Forest. Owing to its location in sub-tropical climate of doon valley, with many seasonal variations over the years, it is home to a large amount of biodiversity including some endangered species of flora and fauna (Isagi *et al.* 1993). The floral diversity of new forest comprises of 267 species of trees, 216 species of shrubs, 447 species of herbs, 83 species of grasses, 41 species of climbers, 32 varieties of bamboos and 185 species of fungi. Among faunal diversity 23 species of mammals, 327 species of birds, 152 species of butterflies, 473 species of moths, 28 species of dragonflies and damselflies, 734 species of other insects, 54 species of spiders, 38 species of Herpetofauna.

Rainfall, temperature, humidity and bright sunshine (hours) data were taken from the FRI Meteorology station. It has humid subtropical to tropical climate with heavy precipitation during May to September and received annual rainfall approximately 2073.3 mm. During the study period temperatures ranged up to maximum 36°C in May and lowest minimum temperature ranged up to 6°C in January. During the study year, the relative humidity fluctuated over the year. Relative humidity was higher in December and lowest in May during the morning readings time whereas, during the day, it was highest in July and lowest in March. The average bright sunshine (hours) was reached the peak at the months of May and lowest in August.

Bamboo poor man's timber has recently enjoyed great appreciation for intensive research and extension activities. This renewable green gold with its versatile uses has found its prime association with rural and tribal livelihood. The Bambusetum of Forest Research Institute has over 32 varieties and species of bamboos. It was established in 1932 and situated in the compartment no. 3 covering an area of 4 ha. This live repository has of subtropical and tropical native and exotic Bamboo species of forestry, ornamental, bio-aesthetic and economic value. Species belongs to various parts of India, Bangladesh, Myanmar, China, Japan, Malaysia, Indonesia, Thailand and south America. Some of the species of Bambusetum are *Bambusa balcooa, B. bambos, B. multiplex, B. nutans, B. tulda, B. vulgaris, Dendrocalamus asper, D. strictus, D. calostachyus, D. longispathus, D. membranaceus, Gigantochloa atroviolacea, Melocalamus maclellandii, Melocanna baccifera, Phyllostachys aurea, Schizostachyum pergracile, Sinarundinaria falcate and Thyrsostachys oliveri* etc.

Selection of species: From the 32 bamboo species present in the bamboosetum of New Forest campus four species *i.e. Dendrocalamus asper, Dendrocalamus strictus, Bambusa tulda, Bambusa vulgaris,* and *Bambusa balcooa* were selected for this study based on their origin and geographic distribution. All of these selected species were native to Indian sub-continent and were widely distributed.

Sample Collection: Bamboo was selected for this research work. Bamboo species selected for this work are *Dendrocalamus asper, Dendrocalamus strictus, Bambusa tulda, Bambusa vulgaris,* and *Bambusa balcooa.* Leaves, Culm, Rhizome were collected from all the selected species. Collected samples were labeled by writing their respective species names, parts collected, and GPS locations so that the chances of mixing of collected samples were decreased.

Drying of Collected Samples: All the collected samples were oven dried upto the point where it lost its whole moisture and easily crushed by hand, to achieve that much of dryness samples were put in oven for 6-8 hours.

Crushing and Grinding of Dried Sample: The dried samples were crushed and grinded by using crusher and grinder into very small particles as much possible and converted into powder form. Then powder sieved using a sieve to get pure powder and removed all big size particles from it. To make sure that different species and their parts were not mixed with each other, they were crushed separately and all the apparatus used in this were cleaned before they were used for crushing and sieving of the next samples.

Capsule Formation: Different Capsules were form from the powder of different samples. Capsule was form from bamboo powder and tungsten powder in 1:1 ratio by its weight. Weight of bamboo powder was ranged between 250mg to 260mg and equal amount of tungsten was added into it. Prepared capsules by using alluvial foil and pressed the capsule properly to remove extra air from the capsule. It made sure the folded sample had an edge length of at least 1mm.

There must be no body fat or sweat on the packing material and had not touch the capsule or other packing material by hands, always worked with tweezers or with gloves. Now these capsules were put into vario MACRO cube CHNOS Elemental Analyzer for estimation of carbon percentage present in the samples.

Use of CHNS for Carbon Estimation: The vario MACRO cube CHNOS Elemental Analyzer performed work quickly and directly determined element concentrations of carbon, hydrogen, nitrogen, sulfur and oxygen in natural, industrial or inhomogeneous environmental samples. It did not required large weights and sample preparation method also did not complex and time consuming. This machine designed for coal, biomass, oil, waste, plants, fertilizer, food, no matter if solid or liquid. The functional principle of machine based on DUMAS method for carbon and nitrogen estimation. This principle consist of combusting a sample of known mass in presence of oxygen in a chamber of high temperature range between 800-900°C. This would lead to release of carbon dioxide, water and nitrogen.

The vario MACRO cube CHNOS Elemental Analyzer had its own computer software, which had shown the readings of samples. Readings were shown in graphical and tabulated form in software and showing nitrogen, carbon dioxide, sulpher dioxide and water but, because this study was based on carbon estimation, so taken only carbon dioxide readings from that table. From these above readings, It was concluded that which species store more carbon than other does and which part had more carbon content than other part in a bamboo species.

Use of Secondary Data: Extracted secondary data on the biomass of the different bamboos to determine which species has the maximum carbon content as a whole plant by destructive analysis method. The data we got from silviculture division of forest research institute. In destructive analysis method bamboos were harvested, silviculture division had some data related to bamboos biomass. This data was used in this thesis work. This study assumed that 50% of the biomass of the bamboo species is its Carbon content (Patricio and Dumago, 2014). But the vario MACRO cube CHNOS Elemental Analyzer helped to know the actual carbon percentage present in different bamboo parts of selected bamboo species. Biomass were multiplied by carbon percentage present in the part, this gave us the carbon content present in the particular component.

Results and Discussion

This study assumes that 50% of the biomass of the bamboo species is its Carbon content (Patricio and Dumago, 2014) (Table 1). CHNS Elemental Analyzer gives the exact value of carbon percentage present in the plant biomass. The readings of CHNS Elemental Analyzer are mentioned below: IN CHNS ELEMENTAL ANALYZER we were able to know the actual carbon percentage in that particular part. After multiplying carbon percentage with biomass we got actual amount of Carbon Content present in the bamboo species Thus, the carbon content of the different components of the bamboo species is given in tabular form as below (Table 2): The carbon content in the components of bamboo largely follows the order: Culm > Rhizome > Leaf. The maximum carbon content is stored in culms (Table 3) followed by rhizome and least carbon content present in leaves in mostly cases but in *Bambusa vulgaris* leaves have slightly more carbon content as compare to rhizomes. The maximum carbon content (Table 3 and 4) is in

Dendrocalamus asper which equals 87.52 t C ha^{-1}. This is followed by *Bambusa balcooa.* with carbon content of 56.48 t C ha^{-1}, *Dendrocalamus strictus* has 47.28 t C ha^{-1}, *Bambusa tulda* has 45.81 t C ha^{-1} and the least content of carbon is in *Bambusa vulgaris i.e*., 33.92 t C ha^{-1}. *Bambusa vulgaris* has slightly higher carbon content in leaf as compared to its branch which is a departure from the general assumption that the branches sequester higher carbon dioxide than the leaves. The carbon content in *Dendrocalamus asper* is maximum on account of its high biomass content along with the site conditions. *Bambusa vulgaris* have relatively lower carbon storage compare to other bamboo species. There are several factors which are responsible for difference like difference at genetic level, difference in age of samples of bamboos which are studied for particular research, difference in soil conditions, rate of photosynthesis, mitigation and adaptation to particular environmental conditions, insect pest attack and may be difference in management practices adopted for different species, which may also cause difference in carbon sequestration. The gregarious flowering in bamboo species is associated with emissions of carbon dioxide as reported by (Liese, 2009) but the socio-economic benefits outweigh the emissions of carbon dioxide into the atmosphere. Another observation is regarding the carbon content in the different components of the bamboo species. The three components considered in this paper are culm and leaf constituting the aboveground biomass rhizome constituting the below ground biomass. The carbon storage is found out to be highest in culm followed by rhizome and leaf. However, in *Bambusa vulgaris* leaf stored more carbon as compare to rhizome. The largest carbon content is however stored in the culm components of bamboo species as most of the bamboo species have the highest biomass storage in the culms. Almost or more than 50% of total carbon content is stored in culm and remaining carbon content stored in other parts. It indicates that culms are very important part for bamboo for carbon sequestration. The internal parameters like photosynthetic mechanism, genetic characters etc, also play a vital role in deciding the storage of carbon in the different species of bamboo. (Yen and Lee, 2011) also point that bamboos in the study area had a C-4 photosynthetic mechanism which is at variance from the general view that bamboos are C-3 plants. This C-4 mechanism is responsible for sequestering high carbon dioxide. C-4 plants show kranz anatomy which increase photosynthesis potential hence ultimately more carbon sequested by C-4 plants as compare to C-3 plants.

Table 1: Biomass storage (t ha^{-1}) and location factors (Reference: Silviculture Division, F.R.I. 2017)

Bamboo species	Leaf (t ha^{-1})	Rhizome (t ha^{-1})	Culm (t ha^{-1})	Temperature (^{o}C)	Average Rainfall (mm)	Location
D. asper	25.35	48.25	107.05	16-36	2073	F.R.I. Dehradun
D. strictus	16.05	32.6	51.9	16-36	2073	F.R.I. Dehradun
B. tulda	3.60	11.95	80.59	16-36	2073	F.R.I. Dehradun

B. vulgaris	23.8	22.05	29.35	16-36	2073	F.R.I. Dehradun
B. balcooa	10.4	11	94.7	16-36	2073	F.R.I. Dehradun

Table 2: Carbon Percentage present in different parts of bamboo species

Bamboo species	CHNS Elemental Analyzer		
	Leaf (C %)	Rhizome (C %)	Culm (C %)
D. asper	45.9	47.1	49.7
D. strictus	44.7	45.9	48.4
B. tulda	43.6	46.8	48
B. vulgaris	44.7	42.8	47.2
B. balcooa	45.2	48	49.1

Table 3: Biomass percentage in parts of bamboo

Bamboo Species	Leaf (%)	Rhizome (%)	Culm (%)
D. asper	14.04	26.71	59.25
D. strictus	15.97	32.42	51.61
B. tulda	3.74	12.43	83.83
B. vulgaris	31.66	29.32	39.02
B. balcooa	8.96	9.47	81.57

Table 4: Carbon content in bamboo

Bamboo Species	Leaf (t C ha^{-1})	Rhizome (t C ha^{-1})	Culm (t C ha^{-1})	Total (t C ha $^{-1}$)
D. asper	11.65	22.62	53.25	87.52
D. strictus	7.17	14.96	25.15	47.28
B. tulda	1.57	5.56	38.68	45.81
B. vulgaris	10.63	9.44	13.85	33.92
B. balcooa	4.7	5.28	46.5	56.48

Conclusion

The analysis of research enhances our understanding of Bamboos which affirms that their carbon storage ability is immense. Bamboo species like the forest species act as carbon sinks when the stands are properly managed and scientifically harvested. They are a versatile species with fast growth and several social, economic and ecological benefits. The bamboos with higher biomass sequestered higher amounts of carbon dioxide thereby helping to reduce the carbon content in the atmosphere, was the species *Dendrocalamus asper*. The highest carbon content was found in the culm component of the different bamboo species followed by rhizome component and lastly the leaf component. Moreover, the concern is raised regarding in case of bamboo species sequestered carbon much which requires further research. The internal mechanisms of bamboo species like genetic ability and photosynthetic ability of bamboo species have not been researched sufficiently.

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