ISSN: 2319-6505

Available Online at http://journalijcar.org

International Journal of Current Advanced Research
Vol 5, Issue 4, pp 736-738, April 2016

International Journal of Current Advanced Research

ISSN: 2319 - 6475

RESEARCH ARTICLE

BAMBOO AS A SUCCESSFUL CARBON SEQUESTRATION SUBSTRATE IN UTTARAKHAND: A BRIEF ANALYSIS

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A R T I C L E I N F O

Article History:

Received 16th January, 2016
Received in revised form 24th February, 2016
Accepted 23rd March, 2016
Published online 28th April, 2016

Key words:

Bamboo; Carbon sequestration; Carbon stock; Climate change; Green house gases; Uttarakhand.

A B S T R A C T

Greenhouse gases are increasing in the earth's atmosphere and causing climate change. Scientist, policy makers, and citizens are trying to determine how to decrease and possibly reverse emissions of greenhouse gases, especially carbon dioxide (CO_2). Carbon sequestration is the capture and secure storage of Carbon by biotic and processes. Carbon sequestration is the process characteristic of the species employed for plantation but depends on the continuous management of the plantation also. Assessment of carbon stocks in vegetation and soil is a basic step in evaluating the carbon sequestration potential of an ecosystem. There are estimates that terrestrial ecosystems could sequester significant quantities of carbon over the next 50 years. The impact of this sequestration could help buy time for other technologies to come on-line by delaying the need for more dramatic decreases in global emissions. There is increasing interest in scientific advances that can be used to further enhance this potential sequestration of carbon in plants. This paper summarizes current research that is addressing few researches which shows that bamboo has proved its applicability as a substrate for sequestering ample amount on carbon. Bamboo as a plantation is being popular in hilly region like Uttarakhand and researches show that it can absorb far more carbon than other plants or soil.

INTRODUCTION

Society is increasingly turning attention toward greenhouse gas emission control with for example the Kyoto Protocol has entered into force. When considering agricultural and forest carbon sequestration, one needs to recognize that the capacity to sequester is limited and an ecological equilibrium will be approached effectively saturating the ecosystems ability to hold carbon. Carbon sequestration is a growing research topic that addresses one important aspect of an overall strategy for carbon management to help mitigate the increasing emissions of CO_2 into the atmosphere.

There are estimates that terrestrial ecosystems could sequester significant quantities of carbon over the next 50 years. Carbon sequestration in terrestrial ecosystems can be defined as the net removal of CO_2 from the atmosphere into long-lived pools of carbon. The pools can be living, aboveground biomass (e.g., trees), wood products with a long, useful life created from biomass (e.g., lumber), living biomass in soils (e.g., roots and microorganisms), or recalcitrant organic and inorganic carbon in soils and deeper subsurface environments. It is important to emphasize that increasing photosynthetic carbon fixation alone is not enough.

This carbon must be fixed into long-lived pools. Otherwise, one may be simply altering the size of fluxes in the carbon cycle, not increasing carbon sequestration.

Global climate change has inspired an increasing interest of scientific and political communities in the study of global carbon storage and carbon balance. Several 'no regret' policies and forest management practices were considered to address the impacts of climate change (Ravindranath *et al*., 2006).

The International Panel on Climate Change (IPCC) has recommended a catalogue of remedial measures to mitigate increasing CO_2 emissions. Among these remedial measures, such as reafforestation, the conversion of agricultural land into agrosilvicultural systems has also been included (IPCC, 2001). There has been very limited study done on bamboo in Uttarakhand and that too in natural plantation systems.

Bamboo represents a fascinating name for a quite extraordinary group of plants. Essentially a family of giant woody grasses, they are used for every conceivable purpose, from scaffolding to boats, cooking utensils to furniture, for food, fuel, landscaping, ornamental display and a thousand other uses.

Their direct and widespread importance to our social and economic wellbeing may be self-evident but, surprisingly, we still know relatively little about most bamboos in the wild. Although their importance to a few threatened species, such as the giant panda, is legendary, the distribution and conservation status of bamboos themselves largely remain a mystery.

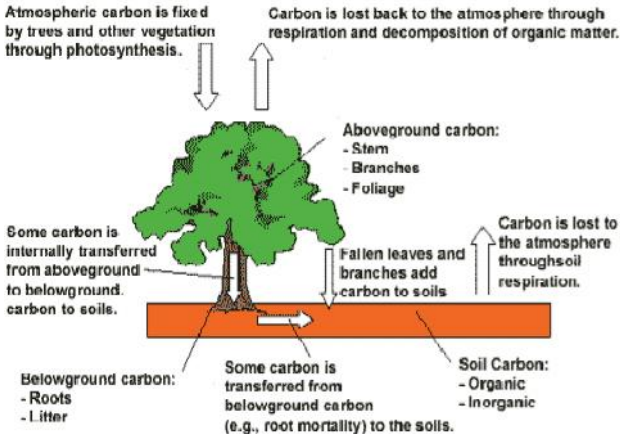

Figure 1 Forests function as carbon sinks, absorbing CO_2 from the atmosphere and sequestering it in tree biomass and forest soils. (Image Courtesy of US EPA)

Bamboo: An overview

Bamboo is an excellent substitute for timbers. In India, particularly in backward countryside where road and communication are not developed, Bamboo plays a pivotal role in construction of houses, house hold implements, and the lots. With the non-availability of timbers from forests for various reasons and also for ban in felling trees by Honorable Supreme Court of India, the importance of bamboo in replacing timbers is gaining more and more grounds. India is the 2nd highest producer of bamboo in the world and 45% of total production of bamboo of the Country is being utilized in paper industries.

The demand of paper industry and also of handicraft, bamboo mat ply, bamboo tiles, etc and lots of other items (of about 1500 documented use of bamboo) is increasing and India has vast international market potentials in the years to come. China and some South East Asian countries are now ruling the roost of the bamboo market at the moment. Bamboo matured in 4-5 years whereas a tree of economic importance requires minimum 60 years to mature. Bamboo can be harvested annually after certain years continuously for about 30-40 years. Bamboo is giving economic security and employment opportunity to unemployed people. Bamboo is ecologically very important plant, as it checks soil erosion and reclaims degraded lands. Bamboo shoots are also a nutrient food items in different forms and this plants have enumerable utilities in our day to day life (Seethalakshmi *et al*., 1998).

Bamboos are multipurpose plants, widely harvested from natural forest and also cultivated. Their uses are dependent upon the characteristics of individual species such as culm strength, flexibility and size. Their contribution to the ecology of an area derives from their ability to recycle nutrients efficiently (Rao & Ramakrishnan, 1989), their ability to protect against soil erosion, and the high nutritive value of their leaves and shoots.

As economically and ecologically important plants, they merit serious attempts to conserve their diversity. Bamboos are distributed throughout the Himalayas, with a variety of different genera adapted to different ecological zones, and an as yet unknown number of species, subspecies and varieties. These are often limited in distribution to a narrow geographic or topographic area. Because of their infrequent flowering their taxonomy has been rather neglected. It is difficult to relate flowering specimens in herbaria to vegetative plants in the field, so that identification of species can be very difficult. In addition, different taxonomists have used different classification systems, recognising different genera according to which parts of the plants they consider to be the most important.

In the hottest and driest outer limits of the Himalayas such as the Siwalik Hills, a limited range of species occurs, including such relatively drought-tolerant species as *Dendrocalamus strictus* and *Bambusa bambos*. Inner valleys of such areas can be classified as semi-arid, and water stress severely limits the distribution of bamboos. The subtropical middle hills of the Western Himalayas are also relatively dry and contain only a few species of bamboo from the genera *Bambusa*, *Dendrocalamus*, and *Drepanostachyum*. The temperate forests are home to a few more, from the genera *Himalayacalamus*, *Thamnocalamus*, and *Yushania*.

They are naturally restricted to cooler, damper sites but are also sporadically cultivated. As they are at the end of their natural range, they are particularly sensitive to environmental degradation. Deforestation, fire or overgrazing can eliminate all bamboos rapidly under such conditions. Reduction in canopy cover can lead to death of even well established bamboos through increased insolation, wind and water stress. Conscious management of forests to protect the understorey, and deliberate cultivation of bamboo crops are necessary if bamboo diversity is to be maintained under such conditions. However, temperature and rainfall are still constraints to bamboo growth, and the genera and species are still sensitive to changes in these and other environmental factors.

Bamboo and Carbon Sequestration

With climate change being unequivocal, reducing CO_2 in our atmosphere has become a primary goal of international efforts. Carbon sequestration is the process characteristic of the species employed for plantation but depends on the continuous management of the plantation also. Assessment of carbon stocks in vegetation and soil is a basic step in evaluating the carbon sequestration potential of an ecosystem. Bamboo, a fast growing, versatile woody grass, is considered one of those materials available in nature with which human inventiveness could interact.

This 'green gold' introduces itself as a cheap and plentiful resource to meet the vast needs of the human population and frequently known as "poor man's timber" (Ram *et al.*, 2010; Tariyal *et al*., 2013). Bamboo has emerged as a precious wood substitute in the last 15 – 20 years (Kumar *et al*., 2010; Tariyal *et al*., 2013).

Being an economic resource with huge potential for humanizing quality of rural and urban life it is also blessed with environmental fortification qualities like carbon sequestration. Preliminary results in bamboo show that it can absorb 12 metric tons of harmful carbon dioxide per hectare from the air, which is twice that of a similar size forest (Choudhary, 2008; Scurlock *et al*., 2000; Tariyal *et al*., 2013). A similar study by Venkatesh *et al*., (2005) concluded that organic carbon increased in soils under all the species of bamboo. Due to their fast growth and high productivity bamboos can be noteworthy as a sink of atmospheric carbon (Nath *et al.*, 2007; Nath *et al.*, 2008; Tariyal *et al*., 2013).

According to a study done by Tariyal *et al*., 2013, where total carbon stock and carbon sequestration potential of four major bamboo species of Uttarakhand (*Bambusa balcooa*, *Bambusa nutans*, *Bambusa vulgaris* and *Dendrocalamus strictus*) were analysed, it was concluded that the highest total carbon stock was in *D. strictus* (381.50 t ha^{-1}) while the lowest stock was shown by *B. vulgaris* (160.11 t ha^{-1}). Contrary to this, the maximum carbon sequestration potential was seen *B. balcooa* (99.81 t $ha^{-1}yr^{-1}$) whereas minimum was observed in *B. vulgaris* (57.77 t $ha^{-1}yr^{-1}$). It was also observed that bamboo shows a good carbon sequestration potential and can be an apt substrate for carbon sequestration.

The fig. 2 shows how bamboo plants absorb more carbon as compared to soil and hence proves its eligibility as an option for carbon sequestration substrate.

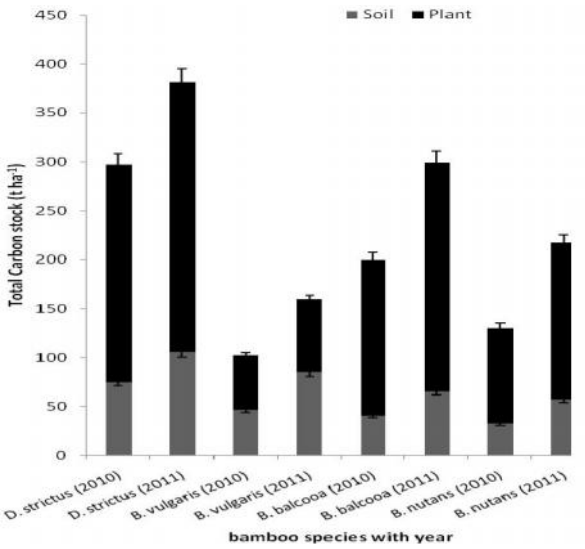

Figure 2 comparative soil and plant carbon stocks in four major bamboo species of Uttarakhand with time (Tariyal *et al*., 2013)

CONCLUSION

The biological transformation capacity of green plants has come in front as an option for secure storage of carbon build up in the atmosphere. Hence, there is a need to quantify carbon pool in plantation crops and the effect of time series data on carbon pool. Total carbon stock (plant + soil) depends on many factors like net primary productivity, biomass, litter biomass, carbon addition from the plant into the soil, soil texture and many more.

Comparative assessment of total carbon stock of all the sites reveals that *D. strictus* was having higher carbon stock and carbon sequestration potential as compared to other bamboo species which may be attributed to its higher productivity, higher biomass, better soil health, higher litter biomass, higher age and best management practice. But it also shows that bamboo has proved to be a good carbon sequestration potential substrate.

The Himalayas are vulnerable to global warming and increasing human activities. Given the level of uncertainty in science and research in the Himalayas, policies should be 'adaptation friendly' Concerns over global warming have stimulated much interest in the possibility of selling carbon (C) sequestration services in international markets. Bamboo has proved itself in many studies that it can be reliable as far as carbon sequestration market is concerned.

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