Bamboo and its role in climate change

Carbon dioxide in the atmosphere has been increasing steadily since pre-industrial times from 280 ppm to the latest record of 395.93 ppm in October 2014 (ref. 1). CO_2 is one of the most important greenhouse gases which is responsible for absorbing energy from the sun, leading to warming of the Earth's atmosphere through the phenomenon of the greenhouse effect and is likely to affect climate change. Currently, 30 billion tonnes of CO_2 equivalent is produced each year by human activities[2]. Carbon management strategies in forests are one of the agendas of the National Action Plan on Climate Change (NAPCC, 2008) to mitigate climate change. Therefore, there is an urgent need to enhance C sequestration in the vegetation and to emphasize the various strategies through management of terrestrial ecosystems.

Bamboos offer a wide range of potential solutions to address the problems that arise due to climate change. Bamboos can be integrated into land use-based climate change mitigation activities such as afforestation/reforestation or avoided deforestation, as they are the fastest growing plants on the planet with growth rate of up to 1.2 m a day. Bamboo is stronger than steel and its root can reduce soil erosion by up to 75%. In this context bamboo offers one of the quickest ways to remove vast amounts of CO_2 from the atmosphere. It can play a significant role in linking climate mitigation to sustainable economic development in the developing world.

Bamboo belongs taxonomically to the subfamily Bambusoideae under the family Gramineae and is widespread in sub-tropic Asia, Africa and Latin America. Worldwide, there are approximately 1500 species of bamboo under 87 genera. In India, bamboo occupies 12.8% of the total forest area of the country comprising 22 genera and 136 species[3]. North East (NE) India is recognized as one of the reserves of bamboo in the country. Out of 136 species of bamboo in India, 89 under 16 genera grow naturally or are cultivated in the tropical and subtropical regions of NE India[4].

Our study on the comparison of carbon stock and sequestration in bamboo and different tree forests under similar climatic conditions reveals that carbon stock is higher in tree forests than bamboo forests, whereas the annual rate of C sequestration was reported to be 22.41 Mg ha^{-1} in bamboo forests under annual selective harvest practice, which was about two times the rate of montane temperate and pine plantations and six times the rate of tropical deciduous forests. These are secondary forests subjected to biotic disturbances due to logging and annual fire (Table 1)[5–7]. Greater C sequestration ability in bamboo forests can be attributed to higher net productivity of the stand which resulted from high culm density and better management practices such as annual harvesting of old culms to maintain the vigour of the forest. Therefore, it shows that bamboo forests might be one of the best vegetations for C sequestration.

Studies have shown that appropriately managed and regularly harvested bamboo can sequester more carbon than bamboo in natural state. Moreover, it can sequester more carbon than fast-growing tropical and subtropical trees under comparable conditions. If bamboo forests are not managed through annual harvesting practices, they would be significantly less effective in carbon sequestration. Due to its renewability, bamboo can take pressure of other forest resources and contribute to avoid deforestation.

Since *Schizostachyum pergracile* bamboo can sequester a huge amount of C (220 Mg C ha^{-1}) in a short period of time of about one year, it has the potential to play a greater role in mitigating the impact of future climate change. One hectare of bamboo can sequester up to 62 tonnes of CO_2 yr^{-1}, whereas 1 ha of young forest can sequester 15 tonnes of CO_2 yr^{-1} (ref. 5). Due to its fast growth, bamboo is widely regarded as an ideal plant for C-sequestration and is expected to play a larger role in reducing CO_2 in the atmosphere.

The major environmental factors that control bamboo growth and distribution are temperature (suitable mean annual temperature from 5°C to 20°C), precipitation (suitable mean annual precipitation ranges from 1000 to 2000 mm) and soil pH (pH ranges from 4.5 to 7.0)[8–10]. Under the present global climate change scenario, continuous global warming would facilitate the spread of bamboo. More or less similar environmental condition, prevailing in NE India would be congenial for the growth and propagation of bamboo on a large scale in degraded areas. In our study on *S. pergracile* bamboo forest of Manipur growing under similar environmental conditions devoid of human activities and because of selective harvesting, the culm population density has increased at an annual rate of 1480 culms ha^{-1}. This will rapidly increase the bamboo forest area and will gradually replace the other species in the near future.

Besides this, bamboo is a remarkable resource for economic development and is readily available in many parts of Africa, Asia and Latin America. If bamboo

Table 1. Comparison of carbon stock and sequestration in bamboo forest and tree forest ecosystems of Manipur, North East India (Mg C ha^{-1})

Forest type	C stock (Mg C ha^{-1})	Carbon sequestration (Mg C ha^{-1} yr^{-1})	Reference
Montane wet temperate forest, Manipur	99.61	12.00	5
Sub-tropical pine forest plantation, Manipur	191.11	10.00	5
Tropical moist deciduous forest, Manipur	10.42	3.49	5
Bambus bambos bamboo plantation	83.30–103.30	21.68–22.41	6
Village bamboo groove	61.05	22.46–23.55	7
Schizostachyum pergracile bamboo forest, Manipur	67.18	22.41	Present study

is not managed through annual harvesting practices, it would be less effective in C sequestration. Therefore, it is essential that culms are harvested annually before they decay and release CO_2 into atmosphere and new culms will emerge with subsequent additional carbon. The harvested bamboo could be used to manufacture durable goods, like building materials for houses, furniture, etc. and can be part of carbon capture and storage.

In NE India, 41.11% of land area is under open or degraded forests. These areas could be utilized for plantation of bamboos which will not only play a vital role in capturing and storing CO_2 efficiently thereby mitigating climate change, but will also boost the economy of people living in and around bamboo forests.

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Seabuckthorn – the natural soil fertility enhancer

Soil contains a number of micro- and macro-elements essential for a plant's growth and development. These mineral nutrients are added to the soil by different natural phenomena. These come either from biodegradable materials or from death and decaying parts of living organisms. They directly or indirectly add a number of organic and inorganic nutrients into the soil which ultimately enrich its fertility. Nitrogen, one of the most essential elements in a plant's nutrition, though abundant in atmosphere, cannot be utilized by the plants directly. While a majority of the plants obtain it from soil, some develop symbiotic association with microbes. Leguminous plants are a well-known example. However, some non-leguminous plants also enter into the symbiotic relationship and contribute significant quantity of fixed nitrogen to their environment.

Hippophae L. is one such non-leguminous nitrogen-fixing plant[1]. It is also the only dominant woody plant inhabiting Ladakh. Covering about 11,500 ha under pure and 30,000 ha under mixed forest plantations[2], the plants of *Hippophae rhamnoides* ssp. *turkestanica* (Figure 1 *a*) have a well-developed tap root system (Figure 1 *b*, *c*). The primary, secondary and tertiary roots are covered with root hairs and form a complex network. This extensive root system reportedly prevents wastage of 90% run-off water and contributes a check on soil erosion to the tune of 95% (ref. 3). The roots enter into a symbiotic association with mycorrhizal fungus *Frankia* (Actinomycetes), leading to the formation of root nodules (Figure 1 *d–f*) which fix a substantial amount of atmospheric nitrogen. This interaction also increases the soil root interface and thereby enhances the nutrition uptake[1]. According to Lu[4], the *Frankia* nodulated roots of seabuckthorn fix nitrogen

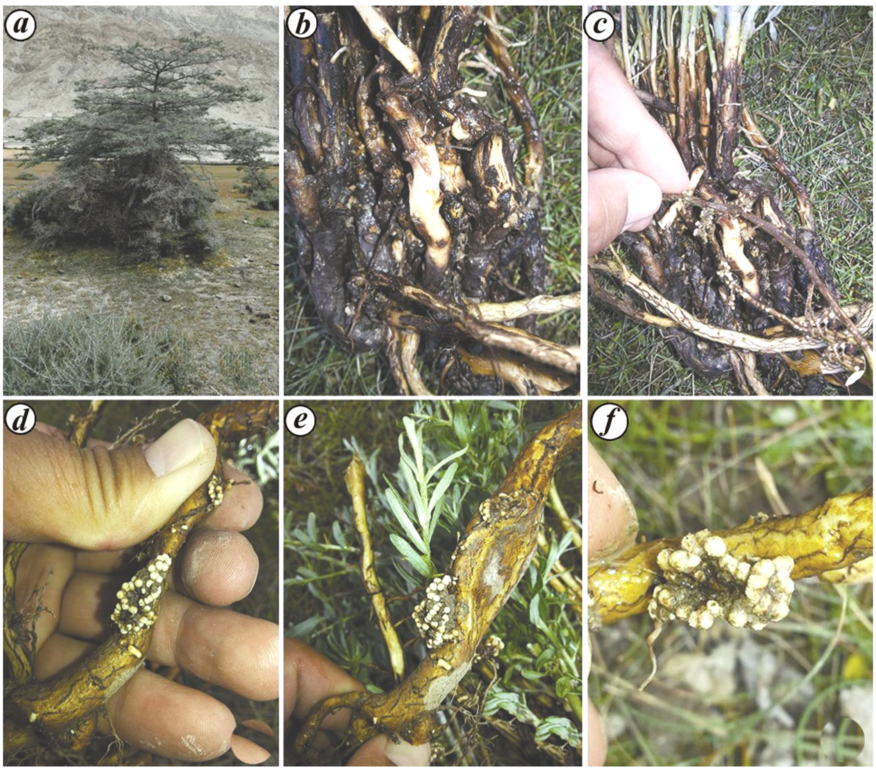

Figure 1. ***a***, An individual plant of *Hippophae rhamnoides* L.; ***a–f***, Root of the mature plant. Mature root without nodule (***b***) and with nodule (***c–f***).