RESEARCH FRONT

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Carbon Sequestration Potential of the Forests of Uttarakhand

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ABSTRACT

Carbon sequestration can be defined as the removal of Carbon dioxide from atmosphere (source) into green plants (sink) where it can be stored indefinitely. These sinks can be above ground biomass (trees) or living biomass below the ground in soil (roots and micro organisms) or in the deeper sub surface environments. Sequestration, which is relatively a new term, can be described as storage of all forms of carbon, including storage in terrestrial, geological and oceanic ecosystem. Through practices and technologies sequestration seeks to quantify and enhance the storage ability of all potential sinks and expand the number and type of sinks in which carbon storage is possible. Forests are carbon stores, and they are carbon dioxide sinks when they are increasing in density or area. There is certainly no doubt that forests do play a significant role in carbon fixation and are the sink for atmospheric carbon. Various studies have shown that forests of Uttarakhand Himalaya show immense potential to sink atmospheric Carbon dioxide on large scale. Present paper gives a brief analysis of the studies done in this field and illustrates the future possibilities.

Key words: Carbon dioxide; Carbon fixation; Carbon sequestration; Potential sink; Terrestrial; Uttarakhand Himalaya.

INTRODUCTION

Forests are very important ecosystems, delivering benefits that go far beyond the supply of timber i.e. fuel wood, fodder, food, bamboos, Non Timber Forest Products (NTFPs), carbon sequestration, climate amelioration, soil and water conservation, recreation, etc. Furthermore, forests play a key role in maintaining water quality, clean air, and help in regulating climate, floods, pollination, biological control of diseases, etc. thus providing various regulating services (Bahuguna and Bisht 2013). 'brake' on climate change. When forest are cleared or degraded, their stored carbon is released into the atmosphere as carbon dioxide (CO_2). The main carbon pools in forest ecosystems are the living biomass of trees and understorey vegetation and the dead mass of litter, woody debris and soil organic matter. Knowledge of the aboveground living biomass density is useful in determining the amount of carbon stored through photosynthesis in the forest stands. Forestry is broadly included under "Land use, Land use change and Forestry" (LULUCF) sector in climate convention. Forestry sector in the developing country provides large and relatively low cost mitigation opportunities (Brown *et al*., 1996; Sathaye and Ravindranath, 2006) to address climate change. Forests, like other ecosystems, are affected by climate change. The impacts due to climate change may be negative in some areas, and positive in others. However, forests also influence climate and the climate change process mainly effecting the changes in the quantum of carbon dioxide in the atmosphere. They absorb CO_2 from atmosphere, and store carbon in wood, leaves, litter, roots and soil by acting as "Carbon Sinks". Carbon is released back into the atmosphere when forests are cleared or burned. Forests by acting as sinks are considered to moderate the global climate.

The State of Uttarakhand is situated in the northern part of India and shares an international boundary with China in the north and Nepal in the east. It has an area of 53,483

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km^2. The State has a temperate climate except in the plain areas where the climate is tropical. The average annual rainfall of the state is 1550 mm and temperatures range from sub-zero to 43^0C (FSI, 2009). Of the total geographical area of the state, about 19% is under permanent snow cover, glaciers and steep slopes where tree growth is not possible due to climatic and physical limitations (FSI, 2009). The recorded forest area of the State is 34,691 km^2, which constitutes 64.79% of its geographical area (FSI, 2009).

FORESTS OF UTTARAKHAND

Majority of the forests of Uttarakhand, India can be broadly divided into six types: subtropical forests, dry deciduous forests, moist deciduous forests, tropical coniferous forests (Pine), temperate broad leaved, and temperate coniferous forests. Biomass values of forest stands in the Himalaya tend to cluster around two very different levels – from a low approximately 200t ha^{-1} for early successional communities such as chir pine, to a high of about 400t ha^{-1} for late successional communities such as oaks and Sal (Singh *et al*, 1992). Many environmental factors (e.g. temperature, precipitation, atmospheric pressure, solar and UV-B radiation, and wind velocity) change systematically with altitude. Therefore, altitudinal gradients are among the most powerful 'natural experiments' for testing ecological and evolutionary responses of biota to environmental changes (Korner, 2007). As mountain regions cover about 27.2% of the total global land area (Blyth *et al*., 2002) and there have been rapid climate changes in mountain regions during the past few decades (IPCC, 2007), understanding the shifts in forest C storage and allocation along altitudinal gradients in mountain regions will help us better predict the response of regional and global C balance to future climate change. Although changes in species composition and distribution, biodiversity and community structure along altitudinal gradients have been well documented in the past few decades (Becker *et al*., 2007; Sharma *et al*., 2009; Sharma *et al*., 2010), the altitudinal patterns of C storage in forest ecosystems remain poorly studied (Zhu *et al*., 2010).

CARBON SEQUESTRATION POTENTIAL

Carbon is stored in various pools in a forest ecosystem: above- and below-ground living biomass, including standing timber, branches, foliage and roots; and necromass, including litter, woody debris, soil organic matter and forest products (Malhi *et al*., 2002). By increasing inventories of "trapped C", C removed from the atmosphere and not released again, forest managers may be able to help buffer the effects of C emissions elsewhere. With the intense focus on the increasing levels of atmospheric CO_2 and the potential for global climate change, there is an urgent need to assess the feasibility of managing ecosystems to sequester and store C. According to a study done by Sharma *et al*., 2010, twenty major forest types of Garhwal Himalaya were assessed with the aim of assessing the stem density, tree diversity, biomass and C stocks in these forest types. Kyoto Protocol recognizes forestry as an acceptable mean of carbon sequestration, and the sector offers possibilities for significant climate change mitigation. As the politics of global warming heats up, countries would be required to furnish detailed statements about their entire carbon budgets. Needless to say forest carbon and trees outside forest would be the major component.

According to one study done by Joshi *et al*., 2013, they studied carbon sequestration potential in *Dalbergia sissoo* and *Eucalyptus* hybrid for two years in Uttarakhand. By the procedure of biomass accumulation, they found out the carbon accumulation in tree. The d.b.h. and height measurement of trees in the selected plots was redone in second year second to assess the change in the d.b.h. The data was subjected to regression analysis to estimate the biomass change of the above ground and below ground components. The net change in biomass between biomass of first year (B_1) and biomass of second year (B_2) was taken as annual biomass accumulation ($\Delta B = B_2 - B_1$). The herb biomass values taken at the time of peak production where used as herb biomass accumulation annually. The sum of ΔB values

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for different components was taken for addition of biomass in trees and herbs. 50% of ΔB (biomass accumulation for each component) was considered as annual carbon sequestration. The total biomass of the tree layer in *Dalbergia sissoo* plantation was 29.51 t ha^{-1} which incremented to 42.85 t ha^{-1} in the second year of which 46.12% is contributed by bole, 23.14% by branch, 4.39% by twig, 8.91% by foliage, 9.32% by stump root, 6.04% by lateral roots and 2.06% by fine roots, and of that 82.34% biomass was stocked in above ground parts and rest 17.66% was stocked in below ground parts respectively. While in *Eucalyptus* hybrid plantation total tree biomass was 43.75 t ha^{-1} which incremented to 59.54 t ha^{-1}in the year two of which about 59.18% is contributed by bole, 8.60% by branch, 1.33% by twig, 8.78% by foliage, 12.48% by stump root, 7.18% by lateral roots and 2.40% by fine roots, here about 82.30% biomass was stocked in above ground parts and rest 17.7% was stocked in below ground parts respectively.

The carbon allocations in different components of seven dominant forest types of Himalayan region were studied by Rana *et. al.*, 1989, and they have concluded that the carbon allocation in seven dominant forest types of the region ranges from 166.8 t C ha^{-1} to 440.1 t C ha^{-1}. Few more studies suggest that the Carbon storage of the central Himalayan forests range from an average of about 175 t c ha^{-1} for chir pine forests to 400 t c ha^{-1} for oak and sal dominant forests (Singh, 2009). Estimation of land use changes, loss of top soil and soil organic carbon content by dominant land use categories have been documented from the available studies in the region.

Another analysis done by Rawat, 2013, in which the study was done on subtropical pine forest and Himalayan moist temperate oak forest. The dominated tree species in the studied Van Panchayats were *Quercus leucotrichophora* and *Pinus roxburghii* while, subordinate species are *Rhododendron arboreum* and *Myrica esculenta*. In this study Carbon stock and sequestration rate were estimated as 50% of the dry weight of biomass and 50% of net primary productivity respectively. Out of the total vegetation biomass (in the year 2008 was 120.07 t ha^{-1}) 93.26% was contributed by trees, saplings and seedlings species, while rest 6.74% by shrubs, herbs and litter. Of the total tree components, the maximum contribution was of the bole (35.23%) and lowest contribution was that of the fine roots (0.57%). In the year 2009 the total vegetation biomass increased to 129.91 t ha^{-1}, of which 92.17% was contributed by trees, saplings and seedlings species, while remaining 7.83% by herbs and shrubs in Anriyakot Van Panchayat. In Bhatkholi Van Panchayat the total vegetation biomass in 2008 was 50.1 t ha^{-1}, of which 86.03 % was contributed by trees, saplings and seedlings species, while rest 14.97% by shrubs, herbs and litter. Of the total tree components, the maximum contribution was of the bole (37.07%) and lowest contribution was that of the fine roots (0.48%). In the year 2009 the total vegetation biomass increased to 58.94 t ha^{-1}, of which 84.68% was contributed by trees, saplings and seedlings species, while remaining 15.32% by herbs, shrubs and litter. Of the average carbon sequestration rate in Anriyakot Van Panchayat forest the contribution of total above ground parts was 3.16 t ha^{-1} yr^{-1} while, the total below ground carbon sequestration rate was 0.72 however, the contribution of shrub, herb and litter was 1.05 t ha^{-1} yr^{-1}. In Bhatkholi Van Panchayat forest the contribution of total above ground parts was 2. 62 t ha^{-1} yr^{-1} while, the contribution of total below ground parts was 0.79 t ha^{-1} yr^{-1} however, the contribution of shrub, herb and litter was 1.02 t ha^{-1} yr^{-1}.

CARBON SINK VALUE OF FORESTS OF UTTARAKHAND

Nearly 20-25% of the annual atmospheric increase of about 8 billion t of carbon is a consequence of deforestation, which results in the depletion of the carbon-sink. Therefore, conservation of forests, including those under the control of local communities in developing countries, is an important component of overall climate strategy. Forest sinks represent much cheaper and easier solution to the build-up of the atmospheric carbon. However, carbon

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sequestration by existing forests, including those managed by local communities are not eligible for carbon trade under the Kyoto Protocol largely because technical difficulties that were foreseen in accurate measurement and verification of carbon gains. Under the Kyoto Protocol only afforestation and reforestation are eligible for carbon trade. However, avoidance of deforestation by conserving forests is more effective solution to the atmospheric rise of CO_2, as what matters is the carbon pool size in a forest, not the rate at which carbon cycles through it. Indeed, plantations would bind carbon rapidly, but they may take 40-50 years to accumulate amounts equal to that are stored in the existing forests. It has been argued that land use changes acceptable under the Protocol should also include soil carbon sequestration, and changes in carbon emitted as a result of afforestation, reforestation and deforestation activities. Carbon loss from soil following deforestation can be very high, particularly in the Himalaya, where slopes are steep, immature and subject to three monsoon months of heavy rainfall.

Figure 1: Oak forest: Shows a tremendous hope for carbon sequestration in Uttarakhand

CONCLUSION

The carbon stored in the living biomass of trees is typically the largest C pool of the forest ecosystem which is directly impacted by deforestation and degradation. The relationships between diversity, biomass and C stocks at varied altitudes can have crucial implications for the management and conservation of C sinks. To stabilize and minimize the atmospheric concentration of GHGs, especially CO_2, immediate reduction in anthropogenic ally accelerated contribution of Carbon at source is utmost important. Reducing use of fossil fuel and replacing them with alternative source of energy, increasing vegetation cover and minimizing use of nitrogen fertilizer. Of the steps undertaken in India concerning global climate change, exploring new and clean energy sources and conserving and sequestering C through conservation of old growth forest and generation of planted forests of improved genotypes, in vegetation and soil are much talked about. Pandey (2002) suggested integration of tools restoration ecology and conservation biology in management of multifunctional

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forests over landscape continuum as a vital option for climate change mitigation. With regard to planted forests, especially for industrial raw materials, removal of whole tree biomass in short rotation which virtually releases stored soil and atmospheric C quickly is not a desirable long term means of C storage and ecosystem sustainability. Maintaining proper density is vital for both natural and planted forests. Application need to be studied for C sequestration potential and the best performing ones be given priority in C forests, bamboo based agro forests and bamboo forestry in wastelands. The C sequestration by the forest vegetation can further be enhanced using a mix option viz (i) Better management of the existing dense forests maintained for biodiversity conservation, watershed value and ecological balance (ii) Improving regeneration of open and degrade forests through human assistance favourably (iii) Multispecies reforestation on non-forest and forest wastelands and iv) Adopting farm forestry in marginal arable lands and crop field's boundaries, creation of large scale C sinks through people's forestry. e.g *smiriti van* (memorial forest), ethno forests, bio carbon oriented watershed forestry and urban forest etc. joint forest management and business houses commercial forests initiative may widen the scope of C forestry.

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