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Enhancing carbon stocks accumulation through forest protection and regeneration. A review

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ABSTRACT

Deforestation has caused serious imbalance in carbon stocks, resulting planet warming. The over-dependence of humankind for fuel wood, non-wood forest produces, food, shelter and other activities has cause reduction in forest land. The rate is more rapid in tropical compare to temperate forest. Several satellite data's and climate model suggest that forest biomass is reducing due to many factors, the anthropogenic activities more than natural calamities or disaster. These phenomena have shown a significant impact in carbon and nitrogen cycle in tropics and temperate regions of the globe. Carbon being a major GHG increases in concentration in atmosphere causing global warming. There is a big challenge in front of forest manager to strategically design forest model with superiority in regenerating a degraded forest by inserting new technologies in National forest management programme. This study focuses on major causes of forest depletion or carbon imbalance and important measure to enhance carbon stock accumulation. Moreover, the research emphasizes serious action to achieve Paris agreement of 2015 to manage carbon emission to optimize global temperature.

Key words: Deforestation, climate changes, carbon emission, carbon source and sink, carbon stocks

Introduction

Forests and trees play a significant role in keeping planet healthy and prosperous. The conversion of forest land to agriculture and livestock areas, has continuously threatened, the diversity of life, forest communities and indigenous peoples. The land degradation, loss of valuable habitats, soil erosion, availability of clean water and carbon cycle are rapidly changing due to land-use changes. Global Forest Resources Assessment (FRA) observed that world's forest area has decreased from 31.6 to 30.6 percent between 1990 and 2015 (SOFO, 2018). Among the major regions of the world Oceania presented maximum whereas, Asia the minimum depletion in forest area during this period. The deforestation has resulted nearly 20% addition of CO_2 to the atmosphere globally (Olofsson *et al*., 2010). The pre analysis of IPCC (Intergovernmental Panel on Climate Change) estimated global carbon budget to be 2.25 t tons since 1870, which is a remarkable deviation from actual number of around 2 t tons of original Paris Climate accord that to be achieved in year 2020 (IPCC, AR5, 2014). All these have raised a serious concern about the global carbon stock and should be addressed properly by the climate scientist and policy makers.

Nearly 40 percent or 250 million extreme rural poor people of the world depend on forests for their livelihoods. Forests and trees provide nearly 20 percent of income for rural people in developing countries. According to an estimate non-wood forest products provide income, food and nutrition for one in five people around the world, including all genders and growers in peril. Around 820 million rural people live on USD 1.25 per day in tropical forest areas. The research reveals that 40% of the world's 230 major watersheds have shown a loss of around more than half of their original tree cover. However managed forests including water and soil conservation has increased globally whereas tropical forest management rank third compare to boreal and temperate forest during the period 1990-2015. The forest has potentiality in providing nearly 40 % of global renewable energy in the form of fuelwood, but it has also resulted forest degradation (SOFO, 2018).

Causes of changes in carbon budget

The natural and anthropogenic activities has been identified as two major causes leading to decline in forest tree species along with changes in global carbon budget (Pandey *et al*., 2016). The climate change and global warming are two important phenomena that show an adverse impact on

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global carbon budget. The carbon budget declines with forest elevation mainly due to modifications in woody growth and biomass due to the fact that food product required for respiration activities is not sensitive to temperature. With the increase in elevation, although nutrient decreases but not affects photosynthesis. As evidenced in submontane and montane forests, cloud immersion effects causes transition in net primary productivity (NPP) that influences the carbon budget (Malhi *et al*., 2017). Similar is the case with terrestrial carbon budget that will also decrease due to higher soil and plant respiration rates caused with increasing temperatures due to global warming (Wood *et al.,* 2012, Cox *et al*., 2013) as evidenced by coupled climate-carbon-cycle models. The increased warming affects other greenhouse gases emissions resulting aerosols reduction which are some other causes of future carbon losses from terrestrial lands (Cox *et al*., 2013). Anthropogenic warming have resulted variations in Madden–Julian oscillation precipitation that moves eastwards along the Equator, upsetting tropical and high-latitude winds, helping in regulating extreme weather events such as hurricanes, flooding and heat waves (Maloney *et al*., 2019).

Some regions of the world mainly temperate forests and grasslands are facing nitrogen (N) saturation due to human activities, retarding changes in the rate of atmospheric N. The IBIS (Integrated Biosphere Simulator) model reveals that N saturation has greatly affected the carbon budget by reducing global NPP (Net Primary Productivity) and NEP (Net Ecosystem Productivity) (Lu *et al*., 2016). The historical and current rates of land use changes traced by a carbon book-keeping model and analyzing Landsat satellite images of Georgian forests reveals a significant loss of nearly 0.8% of the forest cover during 90's decade mainly due to timber harvesting (Olofsson *et al*., 2010). The *Imperata* grasslands in North East India are major sink of CO_2 showing high total biomass carbon production annually. However they are considered an invasive weed causing decline in land productivity. Instead applying other scientific technique, they are traditionally managed through raising fire and harvesting, which greatly influence carbon fluxes and ultimately the carbon dynamics in the region (Pathak *et al*., 2018). Logging is another factor that influences the global carbon cycle. A study of heavily logged forests in Malaysian Borneo exhibit higher total net primary productivity (NPP) and higher allocation to wood causing significant changes in carbon production and sharing in tropical forests (Riutta *et al*., 2018). The forest harvesting in Midwestern US managed forest have resulted in increase in carbon sequestration by 20-30%, decreases long transportation chain emissions, and maintain many desirable stand structural traits that are correlated to biodiversity in the past 100 years (Scott *et al*., 2012).

Mitigations and management of Global carbon budget

Global response in the accumulation of GHG

A study justifies that climate system laws of radiative transfer when inserted in Earth System Models reveals that climate change event causes significant warming due to CO_2 and other GHG emissions in the atmosphere (Anderson *et al*., 2016). General circulation models (GCMs) provokes that GHG emission forces decrease in outgoing longwave radiation and net absorbed solar radiation increases resulting planet warming (Donohoe *et al*., 2014). Changes in the levels of consumption per capita cause an enormous growth, trade structure a very moderate and population growth a very small impact in GHG emissions. Emerging economies like Russia, India, Brazil, Indonesia, and China are causing less extra GHG emissions compared to other countries (Arto and Dietzenbacher, 2014). Forests and trees acting as carbon sinks can play a pivotal role in GHG accumulation as they absorb nearly 2 billion tonnes of CO_2 each year. The forest management strategy should focus on strengthening resilience and adaptive management to weather-related natural disasters reduction. In order to combat climate change, the carbon emissions from forest destruction should be reduced and forest carbon stocks should be enhanced. At the global level, the countries with highest forest cover have started forest management by adopting controls in their National Determined Contributions and National Appropriate Mitigation activities by afforestation, reducing deforestation and forest degradation, increasing forest carbon stocks, conserving forest and adopting agroforestry (SOFO, 2018). In order to meet objectives of emissions and warming targets of December 2015 Paris meeting regarding decarbonization of human activities the unpredicted and transformative technology development, human-made emissions management and fossil fuel consumption should be reduced within given time period (Walsh *et al*., 2017). Various models designed for the conservation of wilderness or maintaining the global carbon budget are found effective and require extensive testing in all major forest biomes and geographical regions (Pandey *et al*., 2015). The best economic solution is to impose a carbon tax on production and use of carbon-based fossil fuels that will enhance the price of carbon-based energy sources and help in minimizing carbon emissions (Harris *et al*., 2017).

Positive-negative emission strategy

The positive emission, due to natural and human-induced activities leading to climate changes and rising global temperature, and negative emission the removal of CO2 through reforestation or afforestation, seems to play a decisive role in maintaining global carbon stocks. Although a challenging task, the policymakers have to work out strategically to design a framework in establishing a balance between positive and negative emission to enhance the carbon budget in near future. Negative emissions technologies like afforestation and reforestation, addition of iron and other nutrients in the Oceans to enhance CO_2 absorption, addition of partly burned biomass referred as 'biochar' to soils enhancing additional CO_2, applying crushed minerals to soil for chemical CO_2 absorption, burning of biomass in power plants and immediate trapping of released CO_2 and storing underground, direct capturing of air and filtering CO_2 using chemicals and storing underground are some of the proposed optional activities for removing CO_2 from the burning climate and repaying carbon debt by the year 2100. However the implementation of most of these strategies are challenging as the infrastructure costs are high and require large land, so they should be mingled carefully to resolve climate change in future (MCC, 2016). The threat due to climate change should be assessed from genes to species to biome level. To overcome the crisis requires a national agenda for reduction of GHG emissions strategically and effectively. The acts and regulation for the safer and sustainable use of forest resources will succeed only due to a common consensus and commitment (Pandey *et al*., 2016).

To manage global decline in carbon budget in tropical forests, applying Reducing Emissions from Deforestation and Forest Degradation (REDD+) model, carbon and biodiversity can be benefitted along with protection of forest fragments, mainly within biomes where contiguous forest cover has declined dramatically (Magnago *et al*., 2015). The mature and over-mature forests shows significant contribution in carbon budget as the seasonally depressed decomposition of organic matter is very slow leading to adequate accumulation of carbon in the biomass and phytodetritus serving as a long-term carbon pool (Vedrova *et al*., 2018). The Mediterranean forests are considered productive forests as they have high soil carbon storage provided the favorable temperatures and soil water content. The root shows a small carbon allocation leading to a large allocation in leaves, with multiannual leaf production, elongated twigs, low LAI and leaf life span producing a high litterfall even under warmer, wetter, and more fertile conditions. These forests propel high soil respiration fluxes, a major component of the global carbon budget which has capacity to balance the high carbon assimilation leading to significant contribution to soil carbon storage (Zribi *et al*., 2015). The domestication of species and forest certification schemes, have potentialities in forest tree conservation and sustain global wilderness (Pandey *et al*., 2016) also plays a significant role in managing carbon budget.

The aboveground litterfall, and litter decomposition are carbon stocks and fluxes of forest ecosystems and are important components of the carbon budgets (Evrendilek *et al*., 2006).They helps in understanding origin and cycling of particulate organic matter and global climate change (Pandey *et al*., 2016). Their production shows significant seasonal variation and independent of forest type and climate factor (An *et al*., 2018). Protection of major carbon sinks like Georgian forests in the Soviet Union combined with economic growth are essential in carbon budgeting (Olofsson *et al*., 2010). The Oak forest in Jeju Island in Korea (An *et al*., 2018), Conifer Mediterranean forests in Turkey (Evrendilek *et al*., 2006) with considerable litter production are sources of carbon stocks in the globe. Nitrogen saturation due to human induced activities as a major factor in reducing carbon budget can be mitigated by increasing CO_2 levels which resulted in increased biomass and also causes reduction in soil mineral N, thus minimizing their impact on the carbon bank (Lu *et al*., 2016). The approaches towards ex-situ techniques like establishing botanic gardens has potentialities in raising the rare and extinct species and genetic heritage not only conserve the species also helps in enhancing carbon budget (Pandey *et al*., 2015).

Tropical forest and carbon budget

Tropical regions, accounts for about one-fifth of anthropogenic greenhouse gas emissions, In tropical forests much carbon is released through deforestation and degradation and they are likely to become a carbon source due to forest loss. These forests are becoming a major source of emissions due to climate change and degradation, driven by animal grazing, agriculture activities and mining (Mitchard, 2018). Presently, tropical forest has become a small carbon source and forest biomass and woodlands add up to 271 ± 16 Pg of carbon as soil organic matter. Carbon loss from degradation and other activities is nearly 2.01 ± 1.1 Pg annum (-1) whereas carbon gain accounts up to 1.85 ± 0.09 Pg annum (-1) (Grace *et al*., 2014). Study of Amazon forest degradation using Landsat imagery reveals that these degraded forests contain 45.1% of the carbon stocks in intact forests. Canopy structure study suggests that variation arises due to forest fire and frequency. The aboveground carbon density (ACD) decreases every year of regrowth. Quantitative analysis using airborne lidar provides a better picture of habitat structure helping to characterize the magnitude, variability and persistence of forest degradation (Rappaport *et al*., 2018). In order to justify the importance of tropical forests as a source or a sink of carbon in a warmer world, the scientific community should not only focus on responses of tropical forest to future climate warming but also give priorities to the research on effects of increased temperature in plant and microbes species composition. The trees as structural and functional basis of forest serves as landscape indicators of prolong alteration due to various stresses (Singh and Pandey, 2017). Plants, Ocean and soils are natural carbon sinks as they absorb CO_2 from the atmosphere. The photosynthesis processes in plants are also natural carbon sink as they fix carbon within their tissues. Besides, nutrient cycling, hydraulic architecture of roots, thermal acclimation versus substrate limitation of plant and microbial communities, heterotrophic versus autotrophic respiration and below-ground carbon allocation are some other parameters for assessment of the impacts of warming in tropical forests (Wood *et al*., 2012).

Conclusion

Thus to conclude the forest that are the major sink of carbon as they store more carbon than they emit, and it changes by season and year, should be conserved effectively. The regeneration and preservation of forest trees becomes necessary to minimize the carbon and other green house gases emission to reduce the temperature and warming in the planet. Moreover, the Paris accord of 2015 to cut short the carbon emission up to 2020 can be achieved only when the alternative source of fuelwood is globally perceived and rural community has finally come to know the significance of forest tree in human life.

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