International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

Role of Forestry in Combating Climate Change

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Abstract: ***Earth's environment has been undergoing changes due to increasing human population and its activities; the most significant changes being the increase in concentration of carbon dioxide and other green house gases in the troposphere. As the forest are so-called carbon sinks have played a critical role in climate change negotiations and constitute a central element in the scheme to limit atmospheric Greenhouse Gas concentrations set out by the Kyoto Protocol. The IPCC fifth assessment report (2014) clearly identifies the forestry sector as one of the key sectors responsible for Greenhouse Gas emissions, while conserving and reducing forest biomass loss can provide a relatively cheap option for climate change mitigation (Stern, 2007). As 4 billion tones of CO_2 are sequestrated in forests and 2.9 billion lost to deforestation and degradation. Today, the use of fossil fuel is responsible for an emission of 7.2 billion tonnes of carbon per year, of which 4.1 accumulate in the atmosphere. At the forest scale, two important concepts must be introduced: stock and flux. Many forest activities contribute to climate change mitigation. The rate of carbon sequestration varies among different forests ecosystems and when it comes to carbon sequestration, all trees are not created equal. The amount of carbon a tree sequesters varies based on the growth rate, age, and species of the particular tree. Hence, forestry is not just a bridge to the future; it should be an important part of any control strategy needed to mitigate climate change.***

Keywords: Climate change, Greenhouse Gas, Biomass, Mitigation, Carbon sequestration

1. Introduction

Earth's environment has been undergoing changes due to increasing human population and its activities; the most significant changes being the increase in concentration of carbon dioxide and other green house gases in the troposphere. Human induced increase in atmospheric CO_2 over the past 140 years is thought to have contributed to average global temperature increase as well as other changes in climate and is attributable mostly to fossil fuel combustion and deforestation worldwide (Hamburg et al., 1997). As the forest are so-called carbon sinks have played a critical role in climate change negotiations and constitute a central element in the scheme to limit atmospheric Greenhouse Gas concentrations set out by the Kyoto Protocol. However, deforestation and destruction of the forests, is a huge significant contributor to climate change. The forest loss and other changes to the use of land account for around 23% of current man-made CO_2 emissions. The efforts to reduce global deforestation could result in the sequestration of 76 billion tons of carbon and 422 million hectare in additional forests (Source: The Nature Conservancy). The term '**global warming'** is often used when discussing climate change. The IPCC fifth assessment report (2014) clearly identifies the forestry sector as one of the key sectors responsible for Greenhouse Gas emissions, while conserving and reducing forest biomass loss can provide a relatively cheap option for climate change mitigation (Stern, 2007).

2. The Major Signs of Global Climate Change

Increasing global temperatures: Global warming—the average global temperature has increased steadily during the last 100 years—about 0.74 degrees Celsius (1.3 degrees Fahrenheit). Temperature increases have occurred in all regions around the world.

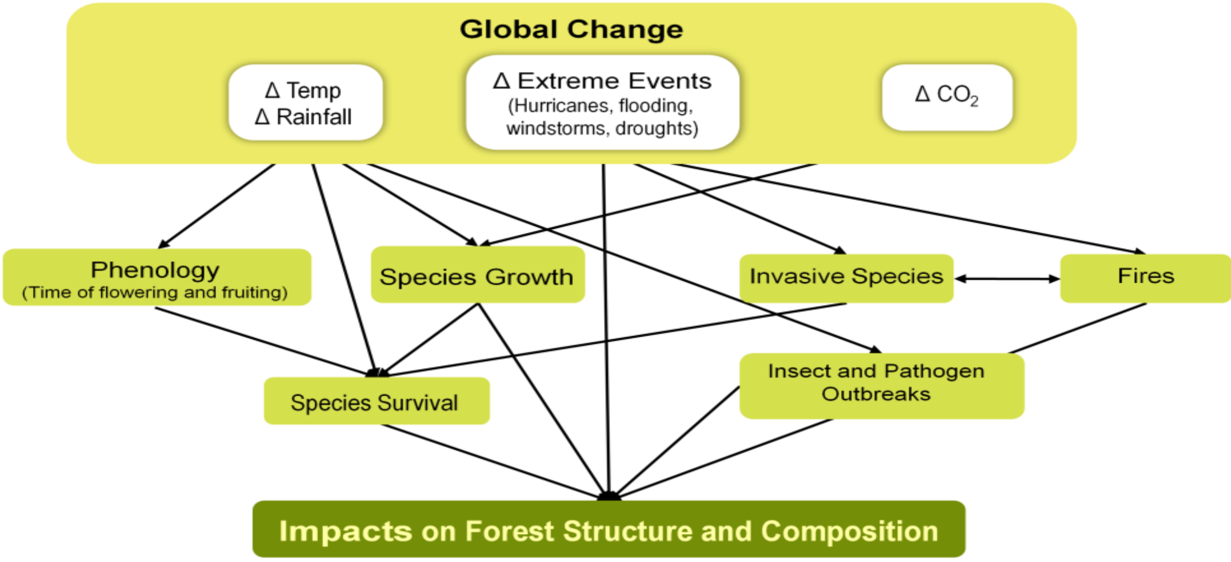
Changes in rainfall: There have been changes in rainfall worldwide, due to changes in surface temperatures of oceans and land areas. Globally, the areas experiencing drought, or periods of extremely dry weather, have increased since the 1970s. While some regions are receiving less rainfall and suffering longer and more droughts, other regions of the world are experiencing much higher levels of rainfall. In many places the seasons or times of year when rain falls are changing. Rain is falling at different times and for shorter or longer periods than in the past.

Decreasing snow cover and melting ice layers at the poles: At the earth's poles, which are found in the most southern and the most northern parts of the world, the climate is very cold. There is ice covering the earth's surface and some covering parts of the sea as well. These areas of ice are called glaciers. More and more of these glaciers are melting because of global warming. Glaciers are also found on very high mountains. Many mountain glaciers are also melting because of warmer temperatures. Example: The ice of this mountain glacier on Mt. Kilimanjaro has almost disappeared. The glacier is over 12,000 years old, but scientists think it could be gone by 2020.

Unusual or Extreme weather events are happening more often: Over the past 50 years, very hot days and nights are happening more often and very cold days and nights are happening less often. Periods of high temperature (heat waves) have become longer and hotter over most land areas. Big storms with heavy winds and rain are happening more often and causing more and more damage.

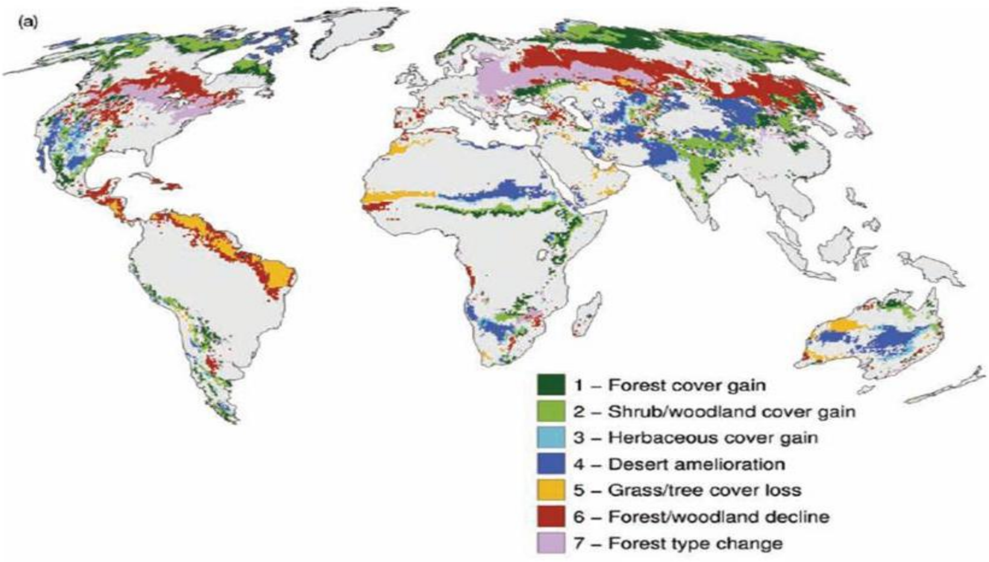
Global forests and climate change: The potential impacts of climate change on forests results from a complex set of linked factors. Some extreme weather events may have direct impacts on forest structure and composition. Example: A windstorm can destroy trees or forests. Changes in temperature and rainfall patterns as well as CO_2 concentrations can have an impact on phenology, the time of flowering and fruiting. It can also affect species growth or survival. Disturbances, such as fires, invasive species, and pathogens can also be affected by global climate change. All these processes can modify forest structure and composition. In some cases, these impacts can lead to the destruction of forests.(Conservational International, 2010)

Impacts of Climate Change on Forests



(Westerling and Bryant, 2014)

Examples of Potential Impacts



Projected changes in terrestrial ecosystems by 2100 relative to 2000

The potential impacts of global change on forests have been studied at various scales. Here a dynamic global vegetation model was used to predict forest cover changes in 2100. You can see the areas with forest decline in dark red and forest type change in mauve.

Contribution of Different Sectors to Climate Change

Greenhouse gas emissions by different sectors includes Agriculture contributes 12%, Forestry and other land use change (12%), Transportation (14%), Industry (21%), Electricity and heat production (25%), Buildings (6%) and Other energy (10%) as per IPCC (2014). Forests provide a critical carbon sink. It is however eroded by deforestation and forest degradation. As 4 billion tones of CO_2 are sequestrated in forests and 2.9 billion lost to deforestation and degradation.

Forests and Mitigation: Storing Carbon on Land

I. Forests and carbon at the global scale

First, you will learn about the carbon cycle at the global scale before downscaling at the forest scale. Today, the use of fossil fuel is responsible for an emission of 7.2 billion tonnes of carbon per year, of which 4.1 accumulate in the atmosphere. The non-accumulated carbon 2.2 billion tonnes per year - is absorbed by the oceans. However, a terrestrial sink of 1 is still missing. Deforestation (mainly tropical) emits 1.6; it means that 2.6 tonnes of carbon per year are absorbed by the biosphere. This is the result of expanding forests in developed countries, the enhancement of ecosystem productivity by higher atmospheric CO_2 concentrations, and a longer growing season in northern latitudes.

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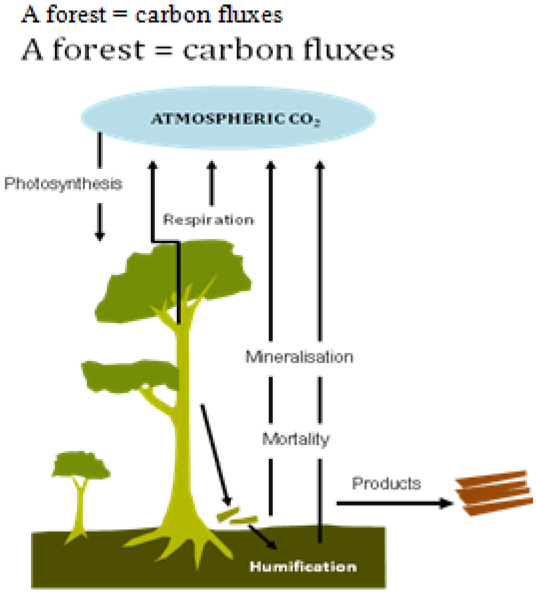
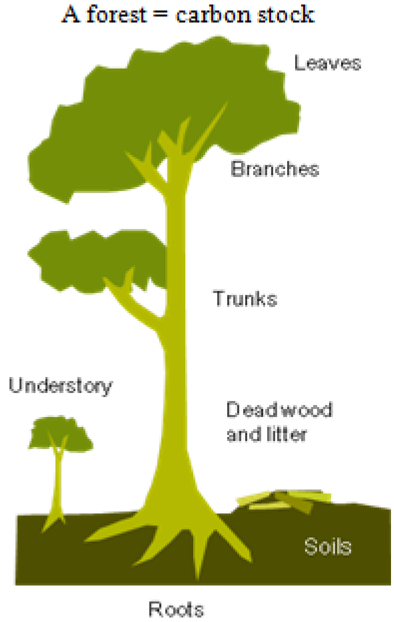
II. Forests and carbon at the ecosystem scale

At the forest scale, two important concepts must be introduced: stock and flux. A forest - or any ecosystem - is a set of carbon stocks. Carbon is everywhere, from the leaves to the soil. A good way to visualise a stock of carbon is to think of the biomass stored in the ecosystem. Biomass is the mass of living biological organisms in a given area or ecosystem at a given time. Almost 50% of the dry biomass is carbon. If the dry biomass of a tree is 2 tonnes, then it contains around 1 tonne of carbon.

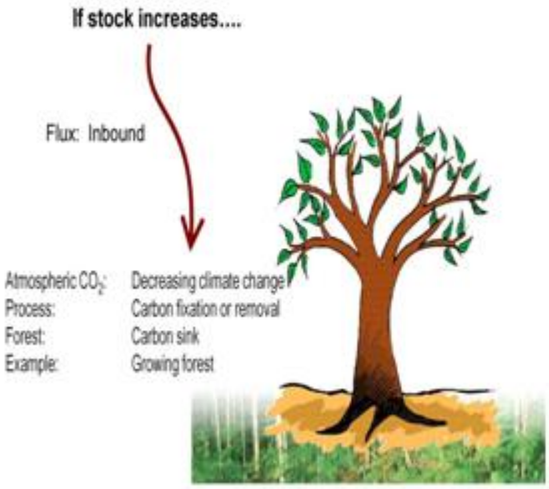


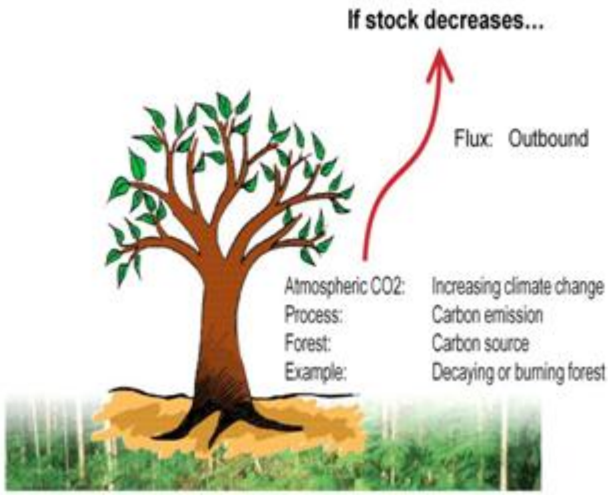


Fluxes

A forest - or any ecosystem - is a set of carbon fluxes. Using the daylight as a source of energy, the leaves absorb carbon dioxide from the atmosphere and transform it through the process of photosynthesis. The products of this process are distributed to the plant and move to the litter and soil when branches or leaves fall and decompose. Other fluxes are emitting CO_2 back in to the atmosphere through respiration and soil mineralisation. Products exported from the ecosystem, such as wood, are also responsible for carbon fluxes. The important fluxes are those between the atmosphere and the biosphere.

Links between stocks and fluxes





If we measure a carbon stock of 30 tonnes of carbon at a given time and a stock of 135 tonnes of carbon after 7 years, it means that, on average, the ecosystem has removed or absorbed 15 tonnes of carbon per hectare per year from the atmosphere.

III. Forest activities that mitigate climate change

Many forest activities contribute to climate change mitigation. 1. Carbon stocks can be increased through plantations or agroforestry. The benefit of these activities is the difference between the growing stock and the baseline, as show on the graph. 2. Existing stocks can be conserved through reducing deforestation. In this case, the benefit of conserving is estimated with reference to the degradation or deforestation scenario. 3. Emissions caused by forest activities can be reduced, for example, by using less energy or fertilizers in forest operations. 4. Biomaterials and bio-energy can be produced to substitute materials or energy that generates greenhouse gases. The first two activities refer to carbon sequestration in the ecosystem, while the last two refer to energy-related emissions.

3. Forests and Adaptation: Supportive Ecosystem Services

I. Mitigation VS Adaptation

Two solutions are being discussed to deal with the impacts of climate change on ecosystems and societies. Mitigation measures address the causes of the problem - increasing greenhouse gas concentrations. For example, mitigation could be measures to reduce energy consumption and promote clean technologies. Adaptation measures deal with the impacts of climate change. The objective of adaptation is to reduce the vulnerability of society and ecosystems. For example, adaptation could involve managing watersheds to reduce landslides or developing alert systems for extreme events.

2. Decreasing vulnerability of society

Forests or natural ecosystems in general can contribute to adaptation by decreasing society's vulnerability, particularly in places with low adaptive capacity. Forests produce goods and ecosystem services that are crucial for society, especially in the context of climate change. According to the Millennium Ecosystem Assessment, three types of ecosystem services are directly beneficial to society: provisioning services (as called goods), regulating services, and cultural services. A fourth type of services (supporting services) contributes to the functioning and stability of ecosystem and thus the production of the other three services. In many cases, forests represent a source of income or a safety net for vulnerable communities (provisioning services). The ecosystem services are vital for many vulnerable communities or sectors, for example concerning water and health (regulating services).

Role of International Agencies

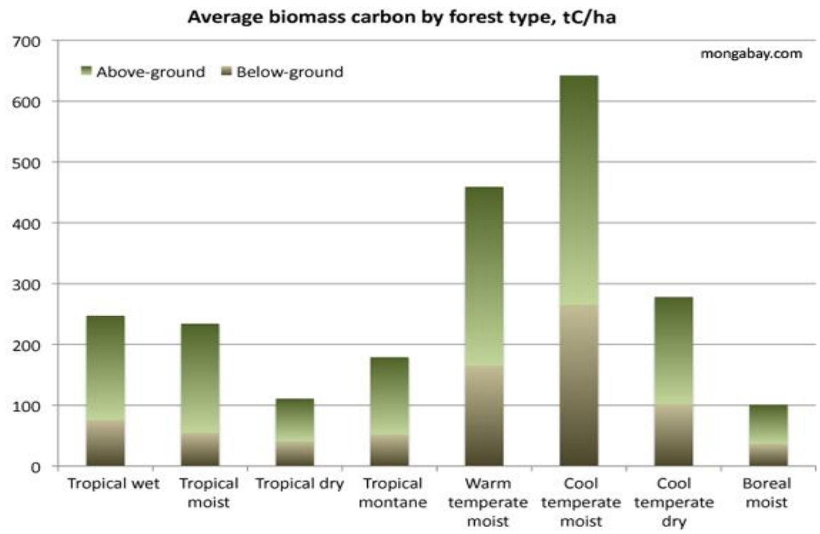
The Kyoto Protocol: Commitment to move away from fossil fuel energy sources to renewable sources of energy viz. hydro, wind, solar power by 38 signatory countries. Commitment to reduce greenhouse gas emissions to 5.6 percent below 1990 levels. Three innovative mechanisms involved are International Emission Trading (IET), Clean Development Mechanism (CDM) and Joint Implementation (JI).

Carbon Sequestration Rates

The rate of carbon sequestration varies among different forests ecosystems and when it comes to carbon sequestration, all trees are not created equal. The amount of carbon a tree sequesters varies based on the growth rate, age, and species of the particular tree. Young, rapidly growing trees uptake far more carbon than mature trees with slower growth rates. Warm and wet climates with long growing seasons also contribute to rapid plant growth and indirectly promote higher rates of carbon sequestration. A recent study in nature found that new rainforests grown on degraded lands, known as secondary forests, are capable of storing up to 11 times more carbon than old growth rainforests. The above- and below-ground biomass in metric tons of carbon stored per hectare are shown as follows:

Forest type	Cool temperate moist forests	Warm temperate moist forests	Cool temperate dry forests	Tropical rainforests	Boreal forests
Carbon storage (tonnes per hectare)	625	500	280	250	100

(Mat, 2010)



(Rhett, 2006)

4. Case Studies

1. Potential Difference of Tree Species on Carbon Sequestration Performance and Role of Forest Based Industry to the Environment (Case of Arsi Forest Enterprise Gambo District) (Siraj and Teshome, 2017)

Siraj and Teshome attempted to evaluate the potential difference of trees species in carbon sequestration performance. This study has been carried out through biomass estimation and quantification in Gambo district. The study finding showed that *G. robusta*, *P. radiata*, *C. lusitanica*, *P. patulla* and *E. grandis* were ranked 1st, 2nd, 3rd, 4th and 5th in carbon sequestration performance in the same condition respectively. Tree plantation, harvesting it and reforesting that same land has importance in socioeconomic appraisal and environmental values if and only if the forest product is used for last long products, but more than 50% of forest enterprise product after sawmill process is used for fuel wood or leftover in and around the industries. Therefore, local sawmill has to be upgraded and has to reduce the by-products or has to use it for further processing. So this study highlighted the role of each tree species in carbon sequestration and emphasizes the need for greater attention to be paid to the selection of trees species in cities to have an appropriate mix of trees species that supports maximum biodiversity and maximizes environmental services.

2. Carbon Sequestration Potential of Agroforestry Systems in India (Murthy et al. 2013)

Carbon storage in agroforestry systems and alternative land use systems for India had estimated a sequestration potential of 68-228 MgC/ha, 25 tC/ha over 96 Mha of land. It was showed that agroforestry could store nearly 83.6 tC/ha up to 30 cm soil depth. Total carbon sequestered in farm forestry with species such as *Eucalyptus sp., Populus deltoides, Tectona grandis, Anthocephalus chinensis trees to be* around 16,400 t/yr. Carbon storage in the system was 1.89-3.45 tC/ha in silvipasture and 3.94 tC/ha in pure pasture in semi arid Uttar Pradesh. An increase in organic carbon of 1.7 to 2.3 times in a silvipastoral system involving *Leucaenea leucocephala, Cenchrus ciliaris and Stylosanthes hamata* was also reported. The carbon in the aboveground and belowground biomass in an agroforestry system is generally much higher than the equivalent land use without trees.

3. Carbon storage and sequestration potential of selected tree species in India (Kaul et al. 2010)

They used a dynamic growth model (CO2FIX) for estimating the carbon sequestration potential of Sal (*Shorea robusta* Gaertn. f.), Eucalyptus (*Eucalyptus tereticornis* Sm.), poplar (*Populus deltoides* Marsh), and teak (*Tectona grandis* Linn. f.) forests in India. The results indicate that long-term total carbon storage ranges from 101 to 156 Mg Cha−1, with the largest carbon stock in the living biomass of long rotation sal forests (82 Mg Cha−1). The net annual carbon sequestration rates were achieved for fast growing short rotation poplar (8 Mg Cha−1yr−1) and Eucalyptus (6 Mg Cha−1yr−1) plantations followed by moderate growing teak forests (2 Mg Cha−1yr−1) and slow growing long rotation sal forests (1 Mg Cha−1yr−1). Due to fast growth rate and adaptability to a range of environments, short rotation plantations, in addition to carbon storage rapidly produce biomass for energy and contribute to reduced greenhouse gas emissions. Extended rotation lengths and reduced thinning intensity could enhance the long-term capacity of forest ecosystems to sequester carbon.

4. Forest carbon stocks and fluxes in physiographic zones of India (Sheikh et al. 2011)

They estimated the total carbon stock in India's forest biomass varied from 3325 to 3161 Mt during the years 2003 to 2007 respectively. There was a net flux of 372 Mt of CO_2 in ASP I and 288 Mt of CO_2 in ASP II, with an annual emission of 186 and 114 Mt of CO_2 respectively. The carbon stock in India's forest biomass decreased continuously from 2003 onwards, despite slight increase in forest cover. The rate of carbon loss from the forest biomass in ASP II has dropped by 38.27% compared to ASP I. Activities like REDD+ can provide a relatively cost-effective way of offsetting emissions, either by increasing the removals of greenhouse gases from the atmosphere by Afforestation programmes, managing forests or by reducing emissions through deforestation and degradation.

Physiographic zone wise biomass details of India for the year 2003

Sr. no.	Physiographic zone	Growing stock (Mm^3)	Biomass in Mt (AGB + BGB)	Forest floor biomass (Mt)	Total Forest biomass (80% of fresh weight) (Mt)
1	Western Himalayas	1159.880	1645.747	24.686	1336.346
2	Eastern Himalayas	549.354	779.474	11.629	632.932
3	North East	486.766	690.669	10.360	560.823
4	North Plains	284.986	404.365	6.065	328.344
5	Easter Plains	390.254	553.730	8.306	449.630
6	Western Plains	104.654	148.493	2.227	120.576
7	Central highlands	241.133	342.142	5.132	277.820
8	North Decan	372.991	529.234	7.938	429.738
9	East Decan	719.584	1021.014	15.315	829.063
10	South Decan	460.812	653.843	9.808	530.920
11	Western Ghats	556.057	788.986	11.835	640.656
12	Eastern Ghats	576.267	817.661	12.265	663.940
13	West Coast	260.443	369.540	5.543	300.066
14	East Coast	250.571	355.533	5.333	288.692
Total		6413.752	9100.438	136.506	7389.556

5. Forest Management in a Time of Rapid Climate Change (Noss, 2002)

Forests, as a class, have proved resilient to past changes in climate, today's fragmented and degraded forests are more vulnerable. Among the land-use and management practices likely to maintain forest biodiversity and ecological functions during climate change are:

- Representing forest types across environmental gradients in reserves.
- Protecting primary forests.
- Avoiding fragmentation and providing connectivity, especially parallel to climatic gradients.
- Providing buffer zones for adjustment of reserve boundaries.
- Practicing low-intensity forestry and preventing conversion of natural forests to plantations.
- Maintaining natural fire regimes.
- Maintaining diverse gene pools.
- Identifying and protecting functional groups and keystone species.

Good forest management in a time of rapidly changing climate differs little from good forest management under more static conditions, but there is increased emphasis on protecting climatic refugia and providing connectivity.

6. Assessing the roles of community forestry in climate change mitigation and adaptation: A case study from Nepal. (Pandey et al. 2016)

They assessed 105 CFs covering a range of forest types managed by socially diverse communities of Nepal. Two point carbon data (2010 and 2013) was analyzed to investigate differences in carbon stocks in these forests following the introduction of a REDD+ pilot program in Nepal. Community forest user groups (CFUGs) have increased forest carbon stocks and that the pilot REDD+ projects are also delivering livelihood benefits which ultimately will help adaptation to adverse climatic conditions. However, the motivation for communities to realize REDD+ carbon incentives may reduce the food supplement capacity of forests by limiting vegetation diversity.

5. Conclusion

Forest restoration and Sustainable management of forests and tree lands all is needed in a time of rapidly changing climate. They are not meant only for mitigating climate change but for providing various productive services like production of goods, protective services comprising protection of soil and water, environmental services including biodiversity conservation, and socio-cultural services by supporting the livelihood of people and poverty alleviation. Bio-energy production from forestry and the substitution of fossil-fuel-intensive products by wood products could be important strategies for mitigating climate change. Planting forest rather than relying on natural regeneration can increase the rate of carbon accumulation in early years and increases the overall quantity of carbon on the site in long run (Sohgen, 2009). Hence, forestry is not just a bridge to the future; it should be an important part of any control strategy needed to mitigate climate change.

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