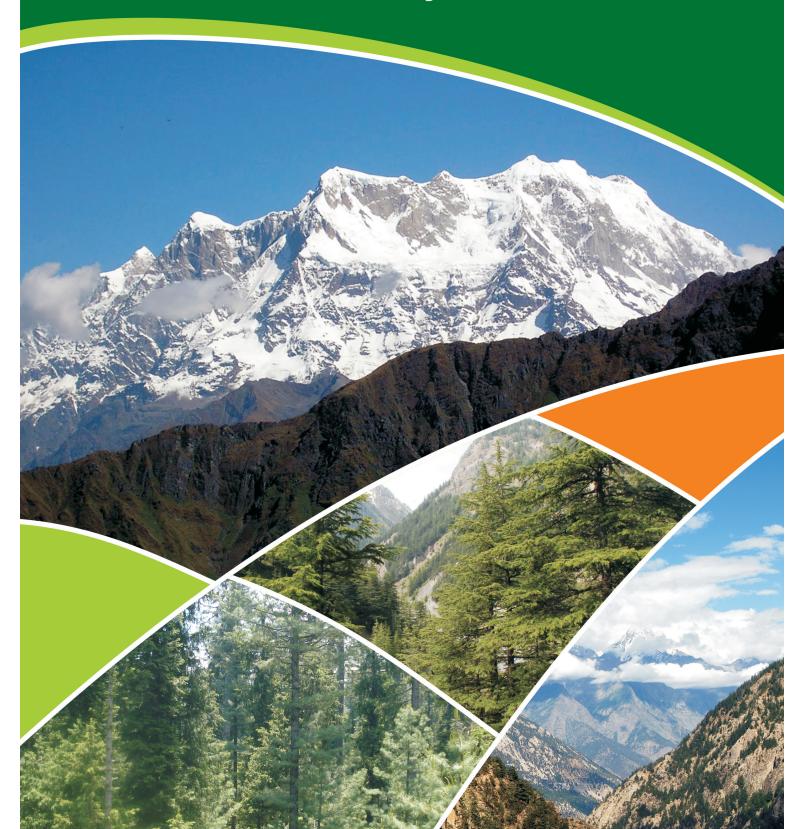
Climate Change Mitigation and Adaptation in Forestry Sector in India



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Biodiversity and Climate Change Division
Directorate of Research
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(An Autonomous body of the Ministry of Environment, Forest and Climate Change, Government of India)
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महानिदेशक भारतीय वानिकी अनुसंधान एंव शिक्षा परिषद्

ाव पानिका अनुसर्वान एवं शिक्षा परिपद् डाकघर न्यू फॉरेस्ट, देहरादून (आईएसओ 9001:2008 प्रमाणित संस्था)

Director General

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FOREWORD

Climate change is a complex issue, which, although environmental in nature, has consequences for all spheres of existence on our planet. It either impacts or is impacted by global issues, including poverty, economic development, population growth, sustainable development and resource management. It is not surprising, then, that solutions come from all disciplines and fields of research and development.

In 1992, countries joined an international treaty, the United Nations Framework Convention on Climate Change (UNFCCC), to cooperatively consider what they could do to limit average global temperature increases and the resulting climate change, and to cope with whatever impacts were, by then, inevitable. At the very heart of the response to climate change, however, lies the need to reduce emissions. In 2010, governments agreed that emissions need to be reduced so that global temperature increases are limited to below 2° Celsius relative to the pre-industrial level.

India is party to the UNFCCC. Country Parties to the convention are to enjoined upon to furnish information in the form of National Communication containing information related to the implementation of the UNFCCC. Consequent upon the submission of Second National Communication, the Ministry of Environment, Forest and Climate Change, Government of India has initiated working on Third National Communication (TNC). One of the additional components of the TNC is the submission of Biennial Update Report (BUR) to the UNFCCC.

ICFRE has been entrusted to furnish information for BUR on 'Forestry Sector: Mitigation and Gaps & Constraints' with an aim to provide update on mitigation actions in forestry sector and updated information on constraints and gaps, and related financial, technical and capacity building needs.

ICFRE completed the task within the prescribed time and the detailed report has been submitted to NATCOM Project Management Cell of the Ministry of Environment, Forest and Climate Change, Government of India. I have great pleasure in presenting this work encompassing various government policies, programmes and action plans contributing to climate change mitigation and adaptation in the forestry sector. My compliments to officers and scientists of the Biodiversity and Climate Change Division, Directorate of Research, ICFRE for accomplishing this study at a very short time. The findings of the study will further help policy makers to develop further climate change mitigation and adaptation programmes in the forestry sector.

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Dy. Director General (Research)

भारतीय वानिकी अनुसंधान एवं शिक्षा परिषद (पर्यावरण, वन एवं जलवायु परिवर्तन मंत्राालय, भारत सरकार की एक स्वायत्त संस्था) पो0 ओ0 न्यू फॉरेस्ट, देहरादून – 248 006 (उत्तराखण्ड)

INDIAN COUNCIL OF FORESTRY RESEARCH AND EDUCATION

(An Autonomous body of the Ministry of Environment, Forest and Climate Change, Government of India) P. O. New Forest, Dehradun – 248 006 (Uttarakhand)

PREFACE

India, being a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), has submitted two National Communications (NATCOM) to UNFCCC, containing information related to the implementation of the UN Convention on Climate Change. Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India, has started working on the Third National Communication (TNC) to the UNFCCC. Before that, there is mandatory requirement of the submission of Biennial Update Report (BUR) to the UNFCCC.

In the past, ICFRE has contributed towards preparations of India's initial and second national communications to the UNFCCC. ICFRE has been entrusted the task of compiling information for BUR on forestry sector with special emphasis on mitigation actions, progress of implementation of actions, their effects, updated information on constraints and gaps, and related financial, technical and capacity building needs in forestry sector for inclusion in the BUR.

In the current study, a detailed literature review and analysis of relevant documents on the subject has been carried out to provide an overview of the current status of knowledge in research activities regarding adaptation to climate change and mitigation aspects of Indian forests. This state of knowledge has been integrated from a wide array of sources like review of existing literature, information from official reports, government web sites, interviews with researchers, stakeholders consultations, workshops and brainstorming sessions to get an update on forest and climate change related issues in the country. Some of the measures on adaptation in forestry sector have also been included.

Findings of the study have been submitted to the NATCOM Project Management Cell of the MoEFCC, New Delhi. It was considered worthwhile to publish the findings in the form of a publication for the benefit of all stakeholders.

I am hopeful that this publication will update the knowledge on mitigation and adaptation efforts in forestry sector being contemplated by Government of India to accomplish the objectives of the Climate Change Convention.



ACKNOWLEDGMENTS

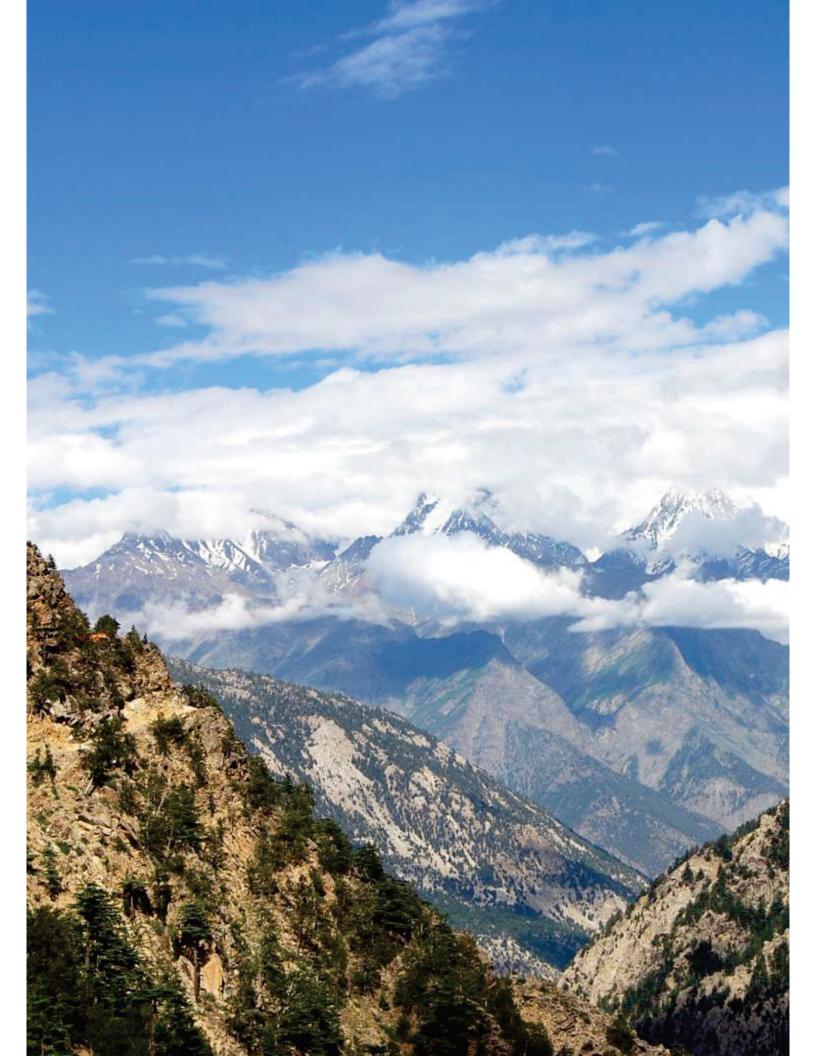
We are highly thankful to the NATCOM Project Management Cell of Ministry of Environment, Forest and Climate Change, Government of India at InsPIRE Network for Environment, New Delhi for providing the financial support to ICFRE for carrying out the project activity on India's First Biennial Update Report-Forestry Sector: Mitigation and Gaps & Constraints.

We are extremely thankful to Dr. Ashwani Kumar, Director General, ICFRE for providing his valuable guidance, support and other facilities for execution of project activity and preparation of this publication. Overall direction and support provided by Dr. G. S. Goraya, Deputy Director General (Research), ICFRE for execution of project activity and bringing out of this publication is greatfully acknowledged.

We take this opportunity to offer our sincere thanks to all officers, scientists and other staff of Biodiversity and Climate Change Division, Directorate of Research, ICFRE who were directly or indirectly involved in the execution of project activity without their support it was not possible to bring out this publication. We are especially thankful to project staff (Dr. Ajeet Kaur, Research Associate and Ms. Nandini Maithani, Junior Project Fellow) for their assistance in preparation of this publication.

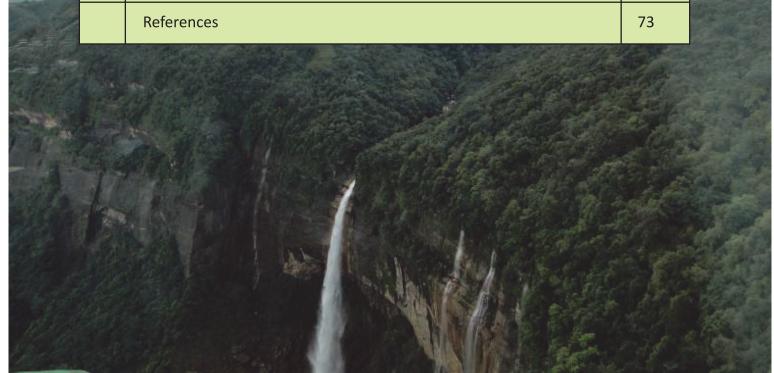
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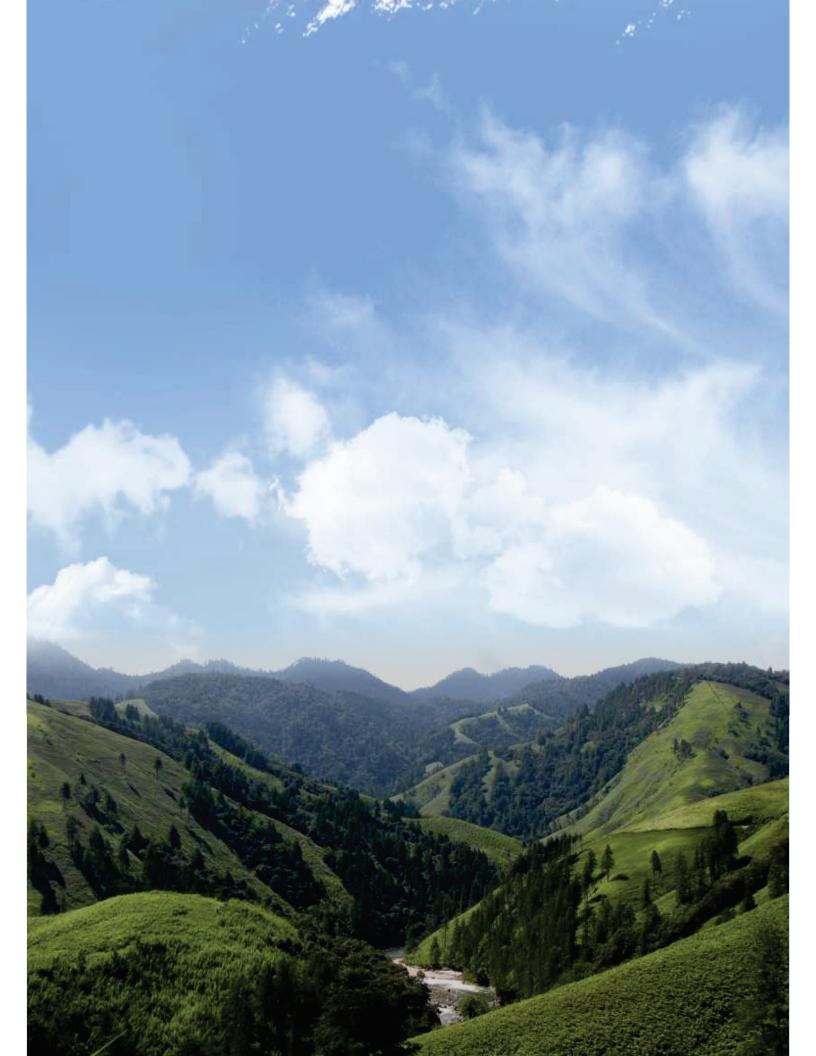




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Abbreviations

AFOLU Agriculture, Forestry and Other Land Use

AP Andhra Pradesh

BUR Biennial Update Report

C Carbon

CAMPA Compensatory Afforestation Fund Management and Planning Authority

CDM Clean Development Mechanism

CFCs Chlorofluorocarbons

CN Conservation

COMAP Comprehensive Mitigation Assessment Process

COP Conference of Parties

EEFP Energy Efficiency Financing Platform
EFCS Enhancement of Forest Carbon Stocks
ENVIS Environmental Information System
FAO Food and Agriculture Organisation

FCA Forest (Conservation) Act
FCS Forest Carbon Stocks
FSI Forest Survey of India
FTC Forest and Tree Cover
GCF Green Climate Fund

GEF Global Environment Facility

GHGs Greenhouse Gases

GIM National Mission for a Green India or Green India Mission

GIS Geographic Information System

GtC Giga tones of Carbon
HP Himachal Pradesh

ICFRE Indian Council of Forestry Research and Education

IHR Indian Himalayan Region

INCCA Indian Network for Climate Change Assessment IPCC Inter Governmental Panel on Climate Change

ISFR India State of Forest Report

ISRO Indian Space Research Organisation

IISc Indian Institute of Science
JFM Joint Forest Management

JFMCs Joint Forest Management Committees

JNNURM Jawaharlal Nehru National Urban Renewable Mission

LED Light Emitting Diode

LULUCF Land use, Land-use Change and Forestry

MDF Moderately Dense Forest

Mha Million Hectare

MoEFCC Ministry of Environment, Forest and Climate Change

MP Madhya Pradesh Mt Million tonnes



MW Mega Watts

NAEB National Afforestation and Eco-development Board

NAP National Afforestation Programme

NAPCC National Action Plan on Climate Change

NATCOM National Communication

NBA National Biodiversity Authority

NMSHE National Mission for Sustaining the Himalayan Ecosystem

NMSKCC National Mission on Strategic Knowledge for Climate Change

NPP Net Primary Productivity

NRSC National Remote Sensing Centre
NTFPs Non-timber Forest Products

OF Open Forest
PAs Protected Areas

PES Payment for Environmental Services

ppb Parts per billion ppm Parts per million

REDD plus Reducing Emissions from Deforestation and Forest Degradation and Role of

Conservation, Sustainable Management of Forests and Enhancement of Forest Carbon

Stocks

R&T Research and Development

SAPCC State Action Plan on Climate Change

SFDs State Forest Departments

SLEM-CPP Sustainable Land and Ecosystem Management- Country Partnership Programme

SLM Sustainable Land Management
SMF Sustainable Management of Forests
SNC Second National Communication

SOC Soil Organic Carbon

SRES Special Report on Emissions Scenarios
TERI The Energy and Resources Institute

UNDP United Nations Development Programme

UNFCCC United Nations Framework Convention on Climate Change

USAID United States Agency for International Development

VCS Voluntary Carbon Standard

VDF Very Dense Forest

ZNLD Zero Net Land Degradation

EXECUTIVE SUMMARY

Forests have come to occupy central stage in global climate change debates due to their important role in climate change mitigation and adaptation and thus their inextricable linkage to human survival. Studies indicate that climate change is altering existing biome types and can cause forest dieback with consequent loss of biodiversity. As a result of active conservation measures/legislation, forest and tree cover in India has been increasing since 1987. India's forests serve as a major sink of CO₂, offsetting around 17% of the total greenhouse gas (GHG) emissions of the country. It is underlined that in the Indian context, carbon service from forest and plantations is one of the co-benefits and not the main or the sole benefit. India is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC). India submitted its Second National Communication (SNC) to UNFCCC in the year 2012. One of the additional requirements before the Third National Communication is the submission of Biennial Update Report (BUR) to the UNFCCC. The information in the BUR is an update on the second national communication by India to UNFCCC. The update covers progress made in climate change mitigation actions and sustainable development achieved through these actions, as well as any other mitigation actions in the forestry sector suitable for inclusion in the BUR since submission of SNC.

For preparation of BUR for the forestry sector, information is gathered and compiled from various sources like Ministerial and Departmental policy statements/websites, State Action Plans on Climate Change, 12th Five Year Plan, India State of Forest Reports, progress reports and updates of various schemes, peer reviewed research publications, relevant legislations & regulatory frameworks and reports from corporate and private entities, Non-Governmental and International Organizations. Information on progress of different missions and programmes launched by Government of India such as Green India Mission, Compensatory Afforestation Fund Management and Planning Authority (CAMPA), Afforestation & Reforestation schemes being implemented, Forest Management and REDD plus etc.

Various forest conservation oriented acts and policies in India are contributing to a reduction in carbon dioxide (CO_2) emissions, stabilisation and improvement of carbon stocks in forests, and conservation of biodiversity. Forest (Conservation) Act, 1980 is one of the most effective legislations contributing to reduction in deforestation. The pace of diversion of forest land for non-forest purposes was around 1,60,000 hectares per annum from 1951 to 1976. However, after the implementation of Forest (Conservation) Act, 1980, the rate of diversion of forests has come down drastically to 35,000 ha annually during 1980-2011.

The National Mission for a Green India (also called 'Green India Mission' - GIM) is one of the eight Missions under the National Action Plan on Climate Change (NAPCC). GIM acknowledges the influence that the forestry sector has on environmental amelioration through climate change mitigation, food security, water security, biodiversity conservation and promoting livelihood security of forest dependent communities. The incremental annual mitigation potential of only the GIM interventions is estimated to be 148.8 million tonnes CO₂ by 2020. This alone has the potential to offset additional 6.4% of the national GHG emissions projected for 2020. According to a report of the Planning Commission of India (now Niti Aayog), carbon capture through activities like continued conservation of Protected Areas (PAs), sustainable management of forests other than PAs, improvement in forest and tree cover, interventions like improved wood burning cook stoves, and increase in forest and tree cover in forest fringe villages together have the potential of capturing 187 million tones of CO₂ per annum. The area covered under proposed forestry actions of State

Action Plans on Climate Change (SAPCCs) in fourteen states is estimated to be 36.9803 million hectares. Objectives of the Green India Mission can also have synergistic impacts when aligned with actions proposed under various other national missions under NAPCC.

Improved cook stoves in the rural areas and forest fringe villages under the National Mission for Enhanced Energy Efficiency and power generation under National Solar Mission in these areas will reduce the rate of forest degradation. National Mission on Sustainable Habitat incorporating programmes like urban forestry has a potential role to play. Forestry support to agriculture is well known. Forestry can support National Mission for Sustainable Agriculture through agro-forestry programmes. Similarly National Mission for Sustaining the Himalayan Ecosystem will increase carbon sink in Himalayan region. Dense forest and vegetation cover will further protect Himalayan region from erosion and fury of flash floods. Long term research programmes on forests and climate change need be undertaken under the National Mission on Strategic Knowledge for Climate Change.

Government of India is in the process of developing its National REDD plus strategy. To facilitate REDD plus at National level among all stakeholders, government has also prepared a 'REDD plus Reference Document'. India's national REDD plus strategy aims at enhancing and improving the forest and tree cover of the country, thereby enhancing the quantum of forest ecosystem services that flow to the local communities. These services include fuelwood, timber, fodder, NTFP and also carbon sequestration.

An internal market mechanism aimed towards climate change mitigation is at a nascent stage in India. In India, carbon trading in the forestry sector is largely under the ambit of Clean Development Mechanism (CDM) of the Kyoto Protocol and voluntary markets. Annual emission reduction through nine CDM Afforestation/Reforestation projects and four forestry projects registered in the voluntary market (VCS) under sectoral scope AFOLU (Agriculture, Forestry and Other Land Use) are estimated to be 3,71,647 and 23,413 tonnes of CO₂ equivalent, respectively. The estimated annual reduction through CDM registered projects in energy sector in India consuming biomass to produce either energy or biogas correspond to 78,03,189 and 2,51,352 tonnes CO₂eq per year, respectively.

For climate change adaptation Sustainable Land and Ecosystem Management (SLEM) a joint initiative under the Country Partnership Programme (CPP) of the Government of India and Global Environment Facility (GEF) was initiated in 2006. The Programme is led by the Ministry of Environment, Forest and Climate Change at the national level, and collaborates closely with state government authorities and other stakeholder groups at the local level. The programme has a cross-cutting and synergetic approach to achieve multiple global environmental benefits in the context of sustaining rural livelihoods from managing natural resources in a sustainable way.

Apart from this initiative, the effective implementation of existing, policies/acts/guidelines, expansion of protected areas, provision/protection of natural corridors, afforestation and reforestation, improved silvicultural practices, promoting community forestry, decreasing pressure on natural forests and forest fire management are different adaptation options under forestry sector. Strategic knowledge gaps, research gaps, technological and capacity building gaps, financial gaps, constraints in data availability for developing various climate related projects are some constraints and limitations that need to be addressed at Institutional level for developing and improving strategic knowledge and planning for adaptation and mitigation of climate change.

INTRODUCTION

1. Background

Climate change as per Inter-governmental Panel on Climate Change (IPCC) refers to a change in the state of the climate, that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2007 a). This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods. International Energy Agency defines climate change as "the change in climate (i.e. regional temperature, precipitation, extreme weather, etc.) caused by increase in the greenhouse effect".

Impacts of climate change will vary at spatial-temporal scale with sectoral basis. The different impacts of climate change are changes in terrestrial biological ecosystems; changes in snow, ice and permafrost; changes in marine and freshwater biological systems, rise in water temperature; more severe droughts and heat waves; rise in sea level, effect on hydrological system; earlier greening of vegetation and longer thermal growing season and acidification of oceans (UNFCCC, 2011a). Long-term measurements of tide gauges and recent satellite data show that global average sea level has risen by approximately 20 cm



(8 inches) since 1901, due both to the expansion of warmer ocean water and the addition of melt waters from glaciers and ice sheets. Arctic summer sea ice cover has shrunk dramatically. The heat content of the ocean has increased. Warming and precipitation changes are altering the geographical ranges of many plant and animal species and the timing of their life cycles. In addition to the effects on climate, some of the excess CO_2 in the atmosphere is being taken up by the ocean, changing its chemical composition (causing ocean acidification). A wide range of other observations (such as reduced Arctic sea ice extent and increased ocean heat content) and indications from the natural world (such as poleward shifts of temperature-sensitive species of fish, mammals, insects, etc.) together provide incontrovertible evidence of planetary-scale warming (The Royal Society, 2014).

Other impacts that may be expected are as follows (UNFCCC, 2011 a):

	Hundreds of millions of	people are r	proiected to be	e exposed to increase	ed water stress:
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- Drought-affected areas will probably increase, and extreme precipitation events, which are likely to increase in frequency and intensity, will increase flood risk;
- Increase in frequency of droughts and floods are projected to affect local crop production negatively, especially in subsistence sectors at low latitudes;
- Runoff and water availability are projected to increase at high latitudes and in some wet tropics, and decrease over much of the mid-latitudes and dry tropics;

There are many natural variations that affect different aspects of climate like temperature, precipitation etc., locally or globally, for days, decades or longer. One such variation is the El Nino Southern Oscillation, an irregular alternation between warming and cooling (lasting about two to seven years) in the equatorial Pacific Ocean that causes global changes of both temperature and rainfall. Volcanic eruptions also alter climate, in part increasing the amount of small (aerosol) particles in the stratosphere leading to a short-term surface cooling lasting typically about two to three years. Slow, recurring variations in Earth's orbit around the Sun, which alter the distribution of received solar energy, may cause drastic change in Earth's global average temperature. All major climate changes, including natural ones, are disruptive. Past climate changes led to extinction of many species, population migrations, and pronounced changes in the land surface and ocean circulation. The speed of the current climate change is faster than most of the past events, making it more difficult for human societies and the natural world to adapt (The Royal Society, 2014).

2. Anthropogenic causes of climate change

Rigorous analysis of all data and lines of evidence shows that most of the observed climate changes of the past several decades cannot be explained just by natural causes but by considering anthropogenic ones. Anthropogenic activities have significantly disturbed the natural carbon cycle by extracting long buried fossil fuels and burning them for energy, thus releasing CO₂ into the atmosphere.

The atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased significantly since the Industrial Revolution began. In the case of carbon dioxide, the average concentration measured at the Mauna Loa Observatory in Hawaii has risen from 316 ppm in 1959 to 396 ppm in 2013. The same rates of increase have since been recorded at numerous other stations worldwide. Since pre-industrial times, the atmospheric concentration of CO₂ has increased by 40%, methane by about 150%, and nitrous oxide has increased by roughly 20%. Increases in all three gases contribute to warming of the Earth, with the increase in CO₂ playing the largest role. CO₂ concentrations began to increase significantly in the 19th century, after staying in the range of 260 to 280 ppm for the previous 10,000 years. Ice core records extending back



800,000 years show that during that time, CO₂ concentrations remained within the range of 170 to 300 ppm throughout many 'ice age' cycles. A doubling of atmospheric CO, concentration from pre-industrial levels (up to about 560 ppm) would, by itself, cause a global average temperature increase of about 1°C. A warmer atmosphere generally contains more water vapour which is a potent greenhouse gas and thus causes more warming. The average surface air temperature of the Earth has increased by approximately 0.8°C since 1850, with faster rate since the mid-1970s. Each of the last three decades has been warmer than any other decade in the instrumental record since 1850. Even if emissions of greenhouse gases were to suddenly stop, Earth's surface temperature could not cool and return to the level in the pre-industrial era for thousands of years. And if emissions continue on their present trajectory, without technological or regulatory abatement, then additional warming of 2.6 to 4.8°C would be expected by the end of the 21st century. Even though an increase of a few degrees in global average temperature does not sound like much, global average temperature during the last ice age was only about 4 to 5°C colder than now. Global warming of just a few degrees will be associated with widespread changes in regional and local temperature and precipitation as well as with increases in some types of extreme weather events. These and other changes (such as sea level rise and storm surge) will have serious impacts on human societies and the natural world (The Royal Society, 2014).

Estimating the pace of the warming, further effect of warming (feedbacks) and other regional climate changes requires the use of mathematical models of the atmosphere, ocean, land, and ice (the cryosphere) built upon established laws of physics and the latest understanding of the physical, chemical and biological processes affecting climate, and run on powerful computers. Models vary in their projections of how much additional warming to expect (depending on the type of model and on assumptions used in simulating certain climate processes, particularly cloud formation and ocean mixing), but all such models agree that the overall net effect of feedbacks is to amplify warming. All model projections indicate that Earth will continue to warm considerably more over the next few decades to centuries.

Box 1. Human emitted greenhouse gases

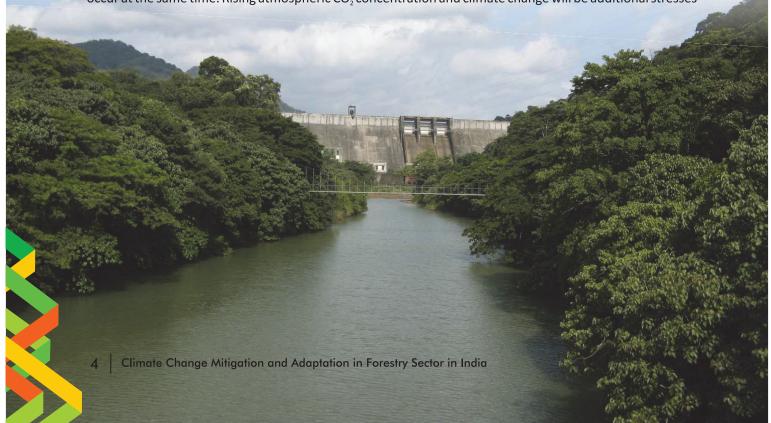
- a) Carbon dioxide (CO₂) levels are increasing mainly because of the combustion of fossil fuels, cement production, deforestation (which reduces the CO₂ taken up by trees and increases the CO₂ released by decomposition of the detritus), and other land use changes. Increases in CO₂ are the single largest contributor to global warming.
- **Methane (CH₄)** levels have risen significantly since pre-industrial times due to human activities such as raising livestock, growing paddy rice, filling landfills, and using natural gas (which is mostly CH₄, some of which may be released when it is extracted, transported, and used).
- c) Nitrous oxide (N₂O) concentrations have raised primarily because of agricultural activities such as the use of nitrogen-based fertilizers and land use changes.
- d) Halocarbons, including chlorofluorocarbons (CFCs), are chemicals used as refrigerants and fire retardants. In addition to being potent greenhouse gases, CFCs also damage the ozone layer. The production of most CFCs has now been banned, so their impact is starting to decline. However, many CFC replacements are also potent greenhouse gases and their concentrations and the concentrations of other halocarbons continue to increase.

3. Forests and climate change

Forests and climate change are intimately intertwined. Forests have regulated the climate, rain, groundwater, soil of the Earth over millennia. Their transpiration act as a regulator of the balance of oxygen and carbon dioxide. The world's forests and forest soils currently store more than one trillion tons of carbon – twice the amount found floating free in the atmosphere. Forests provide a wide range of ecosystem services such as protecting water quality and quantity (including stream flow, drinking water supplies, and groundwater) by retarding runoff, protecting biodiversity, sequestering carbon; providing wood and other non-timber forest products and providing an aesthetic element in the landscape that has both important economic and spiritual values (Heal, 2000). These ecosystem services are generally defined as "the life-support and life-enhancing services of natural ecosystems". Human activities are already impairing the flow of these ecosystem services from the forests on a large scale and if these current trends continue with climate change posing to be an added stressor, a large share of the Earth's remaining natural forest ecosystems will be altered within a few decades.

Since climate has significant influence on the distribution, structure and ecology of forests, changes in climate are likely to alter the configuration of forest ecosystems. Forest sector is important in the context of climate change due to three reasons namely; i) deforestation and land degradation contributes to about 9-11 percent of global $\rm CO_2$ emissions, ii) forest sector provides a large opportunity to mitigate climate change and iii) forest ecosystems are projected to be adversely impacted by climate change, affecting biodiversity, biomass growth and forest regeneration (Ravindranath *et al.*, 2012). Forests support the livelihoods of more than a billion people living in extreme poverty worldwide and provide employment for over 100 million people. They are home to more than 80 percent of the world's terrestrial biodiversity and help protect watersheds that are critical for the supply of clean water to most of humanity. Climate change, however, poses enormous challenges for forests and people.

In many parts of the world, including India, the main drivers of changes in status of forests include land use change, socio-economic pressures, etc. These factors affect the area under forests, biodiversity, species composition, biomass productivity, and regeneration. It is therefore important to assess the impacts of climate change within the framework of changes in environmental and socio-economic factors which may occur at the same time. Rising atmospheric CO₂ concentration and climate change will be additional stresses



on the forests. Mitigation and adaptation are two options for addressing climate change - mitigation seeking to address its causes and adaptation aiming to reduce its impacts. In the forest sector, mitigation strategies comprise reducing emissions from deforestation and forest degradation; increasing the role of forests as carbon sinks; and product substitution, such as using wood instead of fossil fuels for energy and forest products in place of materials whose manufacture involves high greenhouse gas emissions. Mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases. Adaptation encompasses interventions to decrease the vulnerability of forests and forest-dependent people to climate change (FAO, 2012). Mitigation, together with adaptation to climate change, contributes to the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (IPCC, 2014).

3.1 Impact of climate change on forests

The world's forests sequester carbon in the form of CO₂ from the atmosphere in wood, leaves, roots, litter and soil and store more carbon than the entire atmosphere (FAO, 2006). Hence, forests influence climate and climate change process. But like other ecosystems, forests are also affected by climate change either negatively or positively. The impact of climate change on forests is wide spread. Global climatic changes put upto 30 percent of all species at the risk of extinction due to increase in average global temperature of more than 2°C (IPCC, 2007). The biodiversity loss will likely be exacerbated by the impact of changing climatic conditions which result in further losses of habitats, especially in highly fragmented ecosystems (Montoya et al., 2006). The Intergovernmental Panel on Climate Change concluded that the forest ecosystems would be affected by climate and global change in a range of ways through; i) direct impacts on the physical (temperature and precipitation) and chemical (CO, fertilization) environment, ii) impacts on the component species such as geographic range shifts, changing interaction between species altered composition, iii) risk of extinction in respect of a third of the known biodiversity, iv) changes in functions such as diversity, maintenance, productivity, carbon sequestration, water cycling etc., and v) shifts in and possibly enhanced natural disturbances such as fires, pests and extreme climatic events. Climate change has severe implications for the people who depend on forest resources for their livelihoods. India is a mega-biodiversity country where forests account for more than one fifth of the geographical area. With nearly 173,000 villages classified as forest fringe villages, there is a large dependence of communities on forest resources in India (Rawat and Kishwan, 2008).

According to the assessment based on climate projections of the Regional Climate Model of the Hadley Centre (HadRM3) and the dynamic global vegetation model IBIS for A2 and B2 scenarios, 39% of forest grids are likely to undergo vegetation type change under the A2 scenario and 34% under the B2 scenario by the end of this century. However, in many forest dominant states such as Chhattisgarh, Karnataka and Andhra Pradesh (also include Telangana) up to 73%, 67% and 62% of forested grids respectively are projected to undergo change. Net Primary Productivity (NPP) is projected to increase by 68.8% and 51.2% under the A2 and B2 scenarios, respectively, and soil organic carbon by 37.5% for A2 and 30.2% for B2 scenario. The forest vulnerability index which is based on the observed data sets of forest density, forest biodiversity as well as model suggests that upper Himalayas, northern and central parts of Western Ghats and parts of central India are most vulnerable to projected impacts of climate change, while Northeastern forests are more resilient (Chaturvedi *et al.*, 2010). A few studies have been conducted for addressing the impact of climate change on forests in India which are tabulated as below:

Table 1: Impacts of climate change on forests of India

Impact	Source
Most of the mountain forests -sub-alpine and alpine, Himalayan dry temperate and the Himalayan moist temperate forests- are susceptible to the adverse effects of climate change. In contrast, forests in the north-east, southern Western Ghats and the forested region of Eastern India are estimated to be the least vulnerable.	MoEF (2012)
Fragmented forests in northern parts of Western Ghats and in Western and Central India are vulnerable to climate change as well as to high risk of increased temperature, fire and pest attack.	Chaturvedi et al. (2010)
Increase in temperature may result in shift of lower altitude tropical and subtropical forests to higher altitude temperate forests regions, leads to extinction of some temperate vegetation types	Mukhopadhyay (2009)
Decrease in rainfall and the resultant soil moisture stress may replace teak dominated forests with sal trees in central India.	Mukhopadhyay (2009)
Increasing atmospheric CO ₂ may shift in forest types towards wetter forest types in the northeastern region and drier forest types in the northwestern region in the absence of human influence.	Ravindranath <i>et al.</i> (2006)
Increasing atmospheric CO ₂ concentration and climate warming may double net primary productivity	Ravindranath et al. (2006)
Shift of distribution of species in high-elevation ecosystems to higher elevations, with slow rates of vegetation change and constrained colonization	IPCC (2003)
Conversion of dense forests to open forests	Maikhuri <i>et al</i> . (2003)
Increased temperature and rainfall probably increase the productivity of tropical forests	Ravindranath and Sukumar (1998)

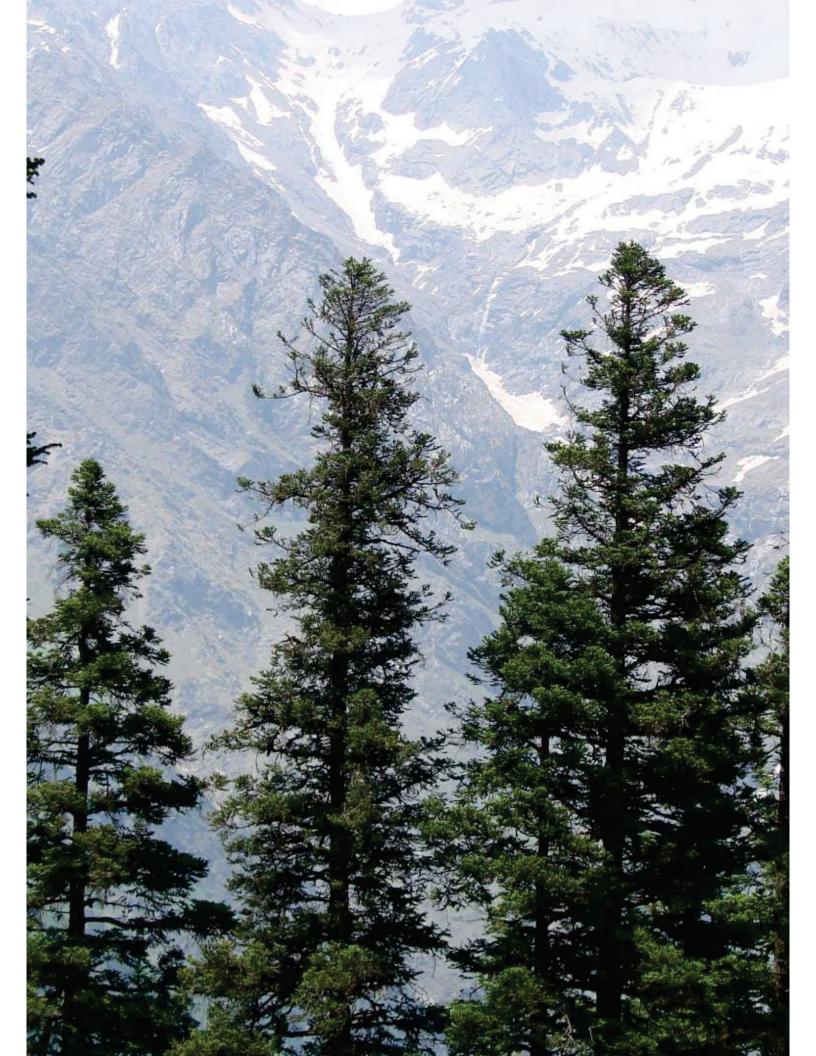
The net primary productivity, a measure of the amount of vegetation matter produced, is likely to increase in the majority of locations due to carbon fertilization. The country's dominant forest cover characterized by moist savanna (32.5%) and dry savanna (33%) is projected to change, and tropical dry (37.2%) and seasonal (28.4%) forests become dominant. Xeric shrublands are set to decrease and woodlands are set to increase in area in the drier regions. In the colder regions, boreal and temperate conifer coverage is expected to decrease while temperate deciduous and evergreen cover is likely to increase in area (Ravindranath *et al.*, 2006).

The impacts of climate change on forests in India are assessed based on the changes in area under different forest types, shifts in boundary of forest types and net primary productivity. This assessment was based on spatial distribution of (i) current climatic variables, (ii) future climate projected by relatively high-resolution regional climate models for moderate SRES A1B climate change scenario, and (iii) vegetation types and NPP as simulated by the dynamic model IBIS v.2 (Integrated Biosphere Simulator). The Indian Network for Climate Change Assessment studied the impact of climate change on the forests for four eco-sensitive regions of India for the 2030's. The four regions for which the study has been carried out include: 1) the Western Ghats, 2) the Himalayas, 3) the coastal regions, 4) the North-Eastern part of India. The NPP for the

Western Ghats region is projected to have increased approximately 20% on an average. The model simulated vegetation change for the Himalayan region, covered by 98 IBIS grids, out of which 55 (56%) are projected to undergo change. The NPP for the Himalayan region is projected to increase by about 57% on an average by the 2030s. The entire coastal region is covered by 96 grids, out of which 29 (30%) are projected to undergo change. NPP for this region is projected to increase by 31% on an average. In the North-Eastern region only about 8% of (or 6 out of 73) forested grids are projected to undergo change. Projections of NPP for this region a 23% increase in NPP on an average. It can be concluded that forests of the four eco-sensitive regions are vulnerable to projected climate change in the short to medium term, even under a moderate climate change scenario. The impacts vary from region to region. The impacts and vulnerability could be higher for other climate change scenarios and in the longer term (INCCA, 2010).

In India, climate change is predicted to alter existing biome types, cause forest dieback, and consequent loss of biodiversity. Many of the impacts of climate change on forests and other natural ecosystems such as loss of biodiversity could be irreversible. There is still large uncertainty with respect to projections of regional climate change, vegetation response models and socio-economic impacts. These shifts will require adaptation of communities dependent on forest resources, as well as adjustment at the regional and national levels.





CLIMATE CHANGE MITIGATION IN FORESTRY SECTOR

'Mitigation' is the effort to control the anthropogenic sources of climate change and their cumulative impacts, notably the emission of greenhouse gases (GHGs) and other pollutants, such as black carbon particles, that also affect the planet's energy balance. Mitigation also includes efforts to enhance the processes that remove GHGs from the atmosphere, known as sinks. Because mitigation lowers the anticipated effects of climate change as well as the risks of extreme impacts, it is part of a broader policy strategy that includes adaptation to climate change impacts (IPCC, 2014). Climate change mitigation depicts actions to limit the magnitude and/or rate of long-term climate change. It generally involves reductions in anthropogenic emissions of greenhouse gases (GHGs). Mitigation policies can substantially reduce the risks associated with human-induced global warming. Mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2014).

The most cost-effective option to reduce emissions in the forestry sector are afforestation, reforestation and improved forest management. An increasing number of communities are also recognizing the value of forest capital for the provision of key services, including, *inter alia*: air quality improvement; flood mitigation; erosion control and landslide prevention; water filtration; and local/regional precipitation cycles. Agro-forestry provides an example of a set of innovative practices designed to enhance overall productivity, to increase carbon sequestration, and that can also strengthen the system's ability to cope with adverse impacts of changing climate conditions. Possible benefits of these activities include mitigation and adaptation, ecosystem services, restoration of degraded land, biodiversity conservation or enhancement, and economic benefits in the form of timber and non-timber forest products. Bioenergy can also play a critical role for mitigation, but there are issues to consider, such as the sustainability of practices and the efficiency of bio-energy systems. Bio-energy technologies are diverse and span a wide range of options and technology pathways. In some regions, specific bio-energy options, such as improved cook stoves, and small-scale biogas and bio-power production, could reduce GHG emissions and improve livelihoods and health in the context of sustainable development (IPCC, 2014).

Table 2.1: Mitigation options and their effects on green house gases (GHGs)

Mitigation Options	Practices and Impacts on GHG's					
Reducing deforestation	C: Conservation of existing C pools in forest vegetation and soil by controlling deforestation, protecting forest in reserves, and controlling other anthropogenic disturbances such as fire and pest outbreaks. Reducing slash and burn agriculture, reducing forest fires.					
	CH ₄ , N ₂ O: Protection of peatland forest, reduction of wildfires.					
Afforestation/Reforestation	C: Improved biomass stocks by planting trees on non-forested agricultural lands. This can include either monocultures or mixed species plantings. These activities may also provide a range of other social, economic, and environmental benefits.					

Forest management	C: Management of forests for sustainable timber production including extending rotation cycles, reducing damage to remaining trees, reducing logging waste, implementing soil conservation practices, fertilization, and using wood in a more efficient way, sustainable extortion of wood energy.		
	CH₄, N₂O: Wildfire behaviour modification.		
Forest restoration	C: Protecting secondary forests and other degraded forests whose biomass and soil C densities are less than their maximum value and allowing them to sequester C by natural or artificial regeneration, rehabilitation of degraded lands, long-term fallows.		
	CH ₄ , N ₂ O: Wildfire behaviour modification.		

Source: IPCC, 2014

2.1 Carbon sequestration by forests in India

Carbon sequestration by forests has attracted much interest as a mitigation approach, as it has been considered a relatively inexpensive means of addressing climate change immediately.

Forest management practices that increase carbon sequestration include:

- 1. Afforestation, reforestation and forest restoration;
- 2. Increase of tree cover through agroforestry, urban forestry and tree planting in rural landscapes;
- 3. Enhancement of forest carbon stocks (in both, biomass and soils) and sequestration capacity through the modification of forestry management practices.

The total growing stock of India's forests and trees outside forests is estimated as 5,658.046 million m³ which comprises 4,173.362 million m³ inside the forests and 1,484.68 million m³ outside the forests. There was a decrease of 389.11 million m³ in total growing stock of the country between two assessments (IFSR, 2011 and IFSR, 2013). Out of this, the decrease inside forests is 325.369 million m³ and that outside the forests is 63.743 million m³. While there is an increase in total forest and tree cover in the country, there is a decrease in the growing stock both inside and outside forest area. The main reason for decline in growing stock within forest area is the loss of 1,991 km² of Moderately Dense Forest (MDF). The conversion of MDF into Open Forest (OF) therefore results in a forest area that is severely depleted in terms of growing stock. Therefore, a large increase in the forest cover under OF may not completely offset the loss in growing stock due to reduction in MDF. Loss of growing stock outside forest area is attributed to harvesting of mature tree crops. According to the India State of Forest Report (FSI, 2013) total carbon stock in forests is estimated to be 6,941 million tonnes. There is an increase of 278 million tonnes in the carbon stock of country as compared to last assessment reported in 2011 (FSI, 2011) which corresponds to the year 2004 (FSI, 2013).

For India, forest area, biomass carbon and carbon per ha was estimated by various workers (Table 2.2). The biomass carbon stock in Indian forests was 7940 Mt C during 1880, which has declined by nearly half over a period of 100 years in 1980 (Richards and Flint, 1994). The carbon estimates also vary depending upon the methods of estimation used and the availability of precise data for various components. In 1986, biomass and soil carbon was in the range of 8.58 to 9.57 GtC (Chhabra and Dadhwal, 2004; Ravindranath *et al.*, 1997).

Table 2.2: Forest area, biomass, carbon (Mt) and carbon (t ha-1) for India

Year	Forest area (Mha)	Components	Biomass (Mt)	Carbon ^a (Mt)	Carbon Density (t ha-1)	References
1880	102.68	AG	-	7940.0	77.3	Richards and Flint (1994)
1980	64.59	AG	-	3425.7	53.0	Richards and Flint (1994)
1984	63.9	Wood (merchantable)	2398.50	1085.16 ^b	16.98	Manhas et al.(2006)
1985	64.2	AG + BG	4432.0	1994.40	31.07	Dadhwal and Nayak (1993)
1986	64.0	AG + BG	8358.0 3	3761.10	58.77	Ravindranath et al.(1997)
1988	63.9	AG + BG	7742.4	3484.08	54.52	Chhabra et al.(2002)
1991	64.01	-	-	4071.00	63.60	Dadhwal and Shah (1997)
1993	64.0	AG + BG	8683.7	3907.67	61.06	Chhabra et al. (2002)
1993	63.9	AG + BG	-	2933.77	46.36	Haripriya (2003)
1994	63.3	Wood (merchantable)	2395.40	1083.81 ^b	17.12	Manhas et al.(2006)
1994	-	-	-	6071	-	FSI (2011)
1995	63.9	AG + BG	4503.8	2026.71	31.72	Lal and Singh (2000)
1995	63.88	-	-	-	4327.36 million ton	ICFRE (2013)
2003	67.83	-	7389.56	3325.30	42.92	Sheikh <i>et al.</i> (2012)
2005	67.7	AG+BG	5178	2343	-	FAO (2006)

AG = aboveground and BG = belowground. (*Carbon proportion taken was 0.45 (Lal and Singh, 2000); *Actual carbon proportions for various forest species (Negi et al., 2003) was taken.}

Table 2.3: Forestry sector contribution to national GHG emission

S. No.	Study	Reference year	National Emissions (Million Tonnes)	Forestry contribution to as % total national emission	Methodology followed for estimation of LULIUCF emissions
1	NATCOM 1, MoEF (2004)	1994	1228.54	1.16 (net emitter)	Default values used
2	SNC, MoEF (2012)	2004	1301.21	-17.1 (net Sink)	Combination of IPCC tier 2 and 3 methodology
3	Kishwan <i>et al.</i> (2009)	2000	1484.62	-9.31(net Sink)	Assessment based on growing stock and primary data on soil organic carbon
4	INCCA (2009)	2007	1727.71	-9 (net Sink)	Combination of IPCC tier 2 and 3 methodology

2.2 Plantations/Afforestation/Reforestation activities in India

As per the National Forest Policy 1952, 33% of the geographical area was to be brought under forest and tree cover. Pursuant to this policy and to meet the demands of goods and services, plantations of various species were raised. Plantations undertaken until 1974-79 were about 3.32 million ha in the country. After that both afforestation and reforestation in India are being carried out under various programmes, namely social

forestry initiated in the early 1980s, Joint Forest Management Programme initiated in 1990, afforestation under National Afforestation and Eco-development Board (NAEB) programmes since 1992, and private farmer and industry-initiated plantation forestry. The "State Compensatory Afforestation Fund Management and Planning Authority" (State CAMPA) is intended as an instrument to accelerate activities for preservation of natural forests, management of wildlife, infrastructure development in the sector and other allied works (Planning Commission, 2011). These efforts have helped in increasing the annual rate of plantation to about 1.50 to 1.80 million ha. The cumulative area afforested during the period 1980 to 2005, including community woodlots, farm forestry, avenue plantation and agroforestry, is about 34 million hectares at an average rate of 1.32 million hectares per year (Chaturvedi *et al.*, 2008). The plantations raised are mainly of Eucalypts, Teak, Acacias, Poplars, Casuarinas, Pines, Bamboos and other miscellaneous species.

The centrally sponsored scheme, National Afforestation Programme (NAP) of National Afforestation and Eco-development Board assists in rehabilitation of degraded forests through JFM Committees. The Programme was formulated by a merger of four centrally sponsored afforestation schemes of the Plan with a view to reduce multiplicity of schemes with similar objectives, ensuring uniformity in funding pattern and implementation mechanism, avoiding delays in availability of funds to the field level and institutionalizing peoples participation in project formulation and its implementation. NAEB is responsible for promoting afforestation, tree planting, ecological restoration and eco-development activities in the country, with special attention to the degraded forest areas and lands adjoining the forest areas, national parks, sanctuaries and other protected areas as well as the ecologically fragile areas like the Western Himalayas, Aravallis, Western Ghats, etc. The scheme was envisaged to be implemented in a participatory mode, by involving two-tier set up namely the Forest Development Agencies and Joint Forest Management Committees.

Forest Survey of India has estimated that about 3.63 million ha of plantation and trees outside forests (TOF) constituting 5.07% of total forest and tree cover presently exists in the country (FSI, 2011). Contiguous plantations in the forests by the state forest departments have enriched the forests of open (10-40% crown cover) and dense category (40-70% crown cover). The plantations have reduced anthropogenic pressure to a considerable extent on the natural forests, and have also met both domestic and industrial demands besides meeting the rural energy demand. Figure 2.1 gives the details and plantation undertaken in India during successive years under NAP.

Tree plantations outside forest land are done by other departments of the State Government under Twenty Point Programme.

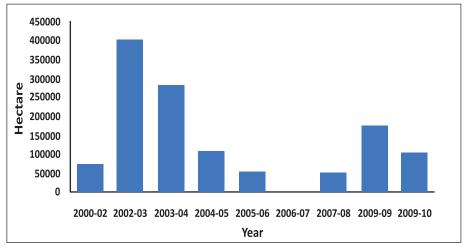


Figure 2.1 Plantation undertaken in India during successive years under NAP (Source: ICFRE, 2010)

National assessments about the rate of carbon flux in selected plant forests in India, made by Raizada et al. (2003) revealed that:

- Planted forests of short-rotation tree species with regular leaf shedding patterns have more capacity for carbon sequestering in litter which decomposes more rapidly than species with annual or bimodal leaf shedding patterns,
- Fast-growing conifers may produce slow decomposing litter leading to accumulation on forest floor, hence, risk for fire damage and decline in ground flora diversity and productivity,
- Mixed planted forests of exotic and native species could be more efficient in sequestering carbon than monocultures, and
- Fast-growing hardy species like Eucalypts would be the ideal choice for wastelands afforestation/reforestation, and softwood species for agri-silvicultural practices in soil of fertile plain areas.

2.3 Low carbon strategy for forestry sector in India

Practices for management of wildlife protected areas and other specifically conserved forest areas resulting in saving and maintenance of existing forest carbon stocks can be grouped under conservation (CN) forests. These are best areas for carbon service. Other forest areas which are subject to harvests and are managed according to prescribed working or management plans can be put under sustainably managed forests (SMF). CN and SMF are the terms used in the Bali Action Plan in the context of Reducing Emissions from Deforestation and forest Degradation (REDD). Management practices of CN and SMF over a period of time would not only result in maintaining existing forest carbon stocks, but would also effect an increment in their quantum due to natural process of growth of conserved vegetation. Use of improved and more energy efficient wood-burning cooking stoves can also help in saving wood biomass and thus contribute towards conservation of forests and trees. Enhancement of forest carbon stocks can be achieved by increasing the forest area, or the carbon density and/or increasing the pool of carbon stored in a given forest or wooded area. In this case, the basic actions would comprise afforestation, reforestation, agroforestry, and energy plantations (fuelwood and biodiesel). Summary of carbon sequestration estimates of different forestry mitigation options is given in Table 2.4.

Table 2.4. Carbon sequestration estimates of different forestry mitigation options

Option	Net Carbon Sequestration				
Conservation and Im	Conservation and Improvement of Existing Forests				
(1)Protected Areas (PAs)	Avoided emissions from deforestation and forest degradation through conservation of existing protected areas (PAs) covering 16 Mha of forest land and accounting for 5 percent of the geographical area of the country are capable of adding 2 tonne of dry biomass per ha on an average every year. Continued protection of PAs will add 47 MtCO ₂ eq to forest carbon sink every year. (16*2.0*0.4=12.8 MtC=47.0 MtCO ₂ eq)				
(2) Sustainable Management of Forests other than PAs	Unlike PAs, other forests (53 Mha) in general are subject to sustainable harvests. Such managed forests are capable of adding 0.8 tonne of dry biomass per ha every year. These forest areas are adding 62.0 MtCO $_2$ eq to the forest carbon sink every year. (53*0.8* 0.4= 16.96 Mt C= 62.0 MtCO $_2$ eq)				
(3) Improvement in Forest and Tree Cover	Aims at improving 1 Mha area each of open forests (OF) and medium dense forests (MDF) with a view to upgrading these forests to the next higher class, i.e., OF to MDF, and MDF to very dense forest category (VDF). Underlying assumption of carbon enhancement is that upgradation of OF to MDF and MDF				

	to VDF will respectively add 0.2 and 0.3 tonnes of dry biomass/ha/ year. This improvement is capable of adding 7.3 MtCO $_2$ eq to the forest carbon sink every year. $(10*(0.2+0.3)*0.4=2.0\text{MtC}=7.3\text{mtCO}_2\text{eq})$
(4) Improved Wood-burning Cook stoves	Avoided emissions from excessive use of fuelwood in cooking stoves in rural areas (800 million people or 160 M families) will significantly contribute to increase in forest carbon stocks by replacing ordinary cooking stoves with improved fuel efficient cooking stoves. Presuming that 75% of the fuel biomass used in rural areas comes from forest, and fuelwood consumption reduced by about 30%, each rural family using fuelwood for energy can save about 300 kg of fuelwood annually. This would result in equal amount of biomass left intact in the forests, thereby offsetting corresponding amount of emissions equal to $58.2\mathrm{Mt}\mathrm{CO}_2\mathrm{eq}$ ($160*0.75*0.3*0.4=14.4\mathrm{MtC}*44/12=52.8\mathrm{Mt}\mathrm{CO}_2\mathrm{eq}$).
Afforestation	
(5) Increase in Forest and Tree Cover in Forest Fringe Villages	Additional area of 17 Mha can be added by creating forest and tree cover in and around 170,000 forest fringe villages. Every year, on an average, 1.7 Mha can be afforested/ reforested. This option will sequester an additional 1 tonne of dry biomass every year. For calculating, CO_2 eq sequestered, it is presumed that 50 percent of the biomass every year will be removed by the villagers for meeting their household needs. This option has the potential of adding 12.5 $MtCO_2$ eq to the forest carbon sink every year. $(17*0.5*0.4=3.4 MtC*44/12=12.5 MtCO_2$ eq)
Wood Products Use N	lanagement
(6) Harvested Wood Products Management (as substitutes)	Wood products store carbon for a long time, and encouraging their use in building construction substituting cement by lumber, and metallic door and window frames and wall cabinets has the potential of saving 2 tonnes of ${\rm CO_2}$ eq emissions for each cubic m of metallic hardware replaced
(7) Replacement of office and domestic furniture using metals with wooden furniture	It is estimated that at present 35% of furniture used in office and homes is made of metals and plastics. Presuming that 50% of the furniture made of metals and plastics can be substituted by wood based furniture every year; such action would result in replacing about 1.5 million m³ of metal and plastic furniture, sequestering an additional 3 million tonnes of CO₂ eq every year.

Source: Planning Commission (2014)



FOREST LEGISLATION ADDRESSING CLIMATE CHANGE MITIGATION

In 1927 the Indian Forest Act was passed which is still in force with few amendments made by different states. However, with the passing of the Government of India Act (1935), forests became entirely the concern of the provinces, although the central government continued to provide technical guidance and advice. The Act provides for Working Plans to be prepared by the State Forest Department, for guiding the village level institutions and the local communities and prescribes ways for sustainable harvest of forest produce.

Various acts and legislations in India are a strong testimony of country's commitment to the philosophy of forest conservation. The Forest (Conservation) Act, 1980 is one of the most effective legislations contributing to reduction in deforestation. This was enacted to reduce indiscriminate diversion of forest land for non-forestry purposes, and to help regulate and control the land use changes in recorded forests. The Act empowers only the Union Government to allow the diversion of forest for non-forestry use. With the enactment of this act, the deforestation and conversion of forest lands to non-forest use has been drastically checked. Now forests are diverted for urgent national developmental need only after rigorous Environmental Impact Assessment of the developmental project. A few important acts, instruments and rules governing the protection and conservation of forests are listed below:

- (I) The National Green Tribunal Act, 2010 is an act of Parliament which enables creation of a special tribunal to handle the expeditious disposal of the cases pertaining to environmental issues. It was enacted under India's constitutional provision of Article 21, which assures the citizens of India the right to a healthy environment. The National Green Tribunal was established on October 18, 2010. The stated objective of the Central Government was to provide a specialized forum for effective and speedy disposal of cases pertaining to environment protection, conservation of forests and for seeking compensation for damages caused to people or property due to violation of environmental laws or conditions specified while granting permissions.
- (ii) National Environment Policy, 2006 is one of the chief drafts concerning environmental policy of India. It encourages imposing of more stringent local level water and air quality standards for receptors. The objectives of the National Environment Policy include conservation of critical environmental resources, intra-generational equity, and livelihood security for the poor, inter-generational equity, integration of environmental concerns in economic and social development, efficiency in environmental resource use and enhancement of resources for environmental conservation.
- (iii) The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006 is a result of the protracted struggle by the marginal and tribal communities of India to assert their rights over the forestland on which they were traditionally dependent. The notification of Rules for the implementation of the Forest Rights Act, 2006 on 1st January, 2008 has finally paved the way to secure community rights or rights over common property resources of the communities in addition to their individual rights. The Act enjoins upon the local communities, to recognize their role in forest and biodiversity protection through sustainable management practices, which will yield long term

- benefits to them (Dash, 2010). The Act is significant as it provides scope and historic opportunity of integrating conservation and livelihood rights of the people. The rules under the Act encourage transition from regulatory mode of forest governance to decentralized forest governance in India.
- (iv) Biological Diversity Rules, 2004 outline the procedures to be followed for access to biological resources (wild plants and animals, crops, medicinal plants, livestock, etc), their commercial utilization, transfer of rights of research, and intellectual property rights related to biodiversity. It also explains that every local body shall constitute a Biodiversity Management Committee with in its area for the purpose of promoting conservation, sustainable use and documentation of biological diversity including preservation of habitats, conservation of land races, folk varieties and cultivars, domesticated stocks and breeds of animals and microorganisms and chronicling of knowledge relating to biological diversity" (NBA, 2008).
- (v) Biological Diversity Act, 2002 is an Act of Parliament for conservation of biological diversity in India. The Act was enacted to meet the obligations under Convention on Biological Diversity, to which India is a Party. It provides conservation of biological diversity, sustainable use of its components and fair and equitable sharing of the benefits arising out of the use of biological resources, knowledge and for matters connected therewith or incidental thereto.
- (vi) The National Environment Tribunal Act, 1995 provides for strict liability for damages arising out of any accident occurring while handling any hazardous substance and for the establishment of a National Environment Tribunal for effective and expeditious disposal of cases arising from such accidents, with a view to giving relief and compensation for damages to persons, property and the environment and for matters connected therewith or incidental thereto. This act is based on decisions taken at the United Nations Conference on Environment and Development held at Rio de Janeiro in June, 1992, in which India participated, calling upon the States to develop national laws regarding liability and compensation for the victims of pollution and other environmental damages.
- (vii) The National Forest Policy, 1988 ensures environmental stability and maintenance of ecological balance including atmospheric equilibrium which is vital for sustenance of all life forms, human, animal and plant. The basic objectives of the policy was maintenance of environmental stability through preservation, conserving the natural heritage of the country by preserving the remaining natural forests with the vast variety of flora and fauna, checking soil erosion and denudation in the catchments areas of rivers, lakes, reservoirs in the interest of soil and water conservation, for mitigating floods and droughts and for the retardation of siltation of reservoirs, checking the extension of sand-dunes in the desert areas of Rajasthan and along the coastal tracts, increasing substantially the forest/tree cover in the country through massive afforestation and social forestry programmes, especially on all denuded, degraded and unproductive lands, meeting the requirements of fuelwood, fodder, minor forest produce and small timber of the rural and tribal populations, increasing the productivity of forests to meet essential national needs, encouraging efficient utilisation of forest produce and maximizing substitution of wood and creating a massive people's movement with the involvement of women, for achieving these objectives and to minimize pressure on existing forests.
- (viii) The Environment (Protection) Act, 1986 amended in 1991 came into force on November 19, 1986.. It is an act to provide for the protection and improvement of environment and for matters related to it. Environment Protection Act, 1986 came into force soon after the Bhopal gas tragedy. The main objective of the act was to provide the protection and improvement of environment. It specifies that the State shall protect and improve the environment and also to safeguard the forests and wildlife of the country.

- (ix) The Forest (Conservation) Act, 1980 amended in 1988 has five sections which deal with conservation of forests. It was enacted with the twin objectives of restricting the use of forest land for non-forest purposes, and preventing the de-reservation of forests that have been reserved under the Indian Forest Act, 1927. However, in 1988 the Act was further amended to include two new provisions where it sought to restrict leasing of forest land to private individuals, authorities, corporations not owned by the Government, and to prevent clear felling of naturally grown trees. The Act provides for punishment, including imprisonment, for the contravention of the provisions of the Act.
- (x) The Wild Life (Protection) Act, 1972, amended 1993 was enacted for protection of plants and animal species. Before 1972, India only had five designated national parks. Among other reforms, the Act established schedules of protected plant and animal species; hunting or harvesting these species was largely outlawed. The Act provides for the protection of wild animals, birds and plants; and for matters connected therewith or ancillary or incidental thereto. It extends to the whole of India, except the state of Jammu and Kashmir which has its own wildlife act. It has six schedules which give varying degrees of protection. Schedule I and part II of Schedule II provide absolute protection offences under these are prescribed the highest penalties. Species listed in Schedule III and Schedule IV are also protected, but the penalties are much lower. Schedule V includes the animals which may be hunted. The plants in Schedule VI are prohibited from cultivation and planting.
- (xi) The Indian Forest Act, 1927 seeks to consolidate the law relating to forests, the transit of forest produce and the duty that can be levied on timber and other forest produce. This Act provides definitions for forest-produce and includes: trees and leaves, flowers and fruits, and all other parts or produce not here in before mentioned, of trees plants not being trees (including grass, creepers, reeds and moss), and all parts or produce of such plants, wild animals and skins, tusks, horns, bones, silk, cocoons, honey and wax, and all other parts or produce of animals, and peat, surface soil, rock and minerals (including limestone, laterite, mineral oils, and all products of mines or quarries).

3.1 Paradigm shift in forest governance in India

The first Forest Policy of independent India was formulated in 1952. The Forest Policy of 1952 declared that village communities should not be permitted to use forests at the expense of national interest. The enactment of the Forest (Conservation) Act 1980 was the first transition in forest governance from commercialized use of forest to conservation. The pace of diversion of forest land for non-forest purposes was around 1,60,000 hectares per annum from 1951 to 1976. However, after the implementation of Forest (Conservation) Act, 1980, the rate of diversion of forests has come down drastically to 35,000 ha annually during 1980-2011 (Figure 3.1) (ICFRE, 2010).

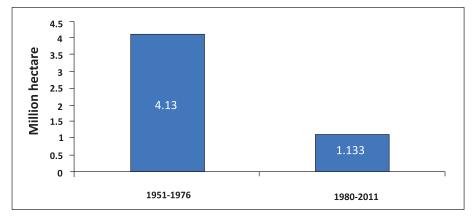


Figure 3.1 Diversion of forest land before and after Forest (Conservation) Act, 1980

The National Forest Policy 1988 was a paradigm shift in the forestry sector. It differed from the previous policies of independent India. In the past, forests were being looked upon merely as a source of revenue. The objective of the 1988 policy was to ensure that the rights of the forest dependent people are protected. The ecological security was the primary goal of this policy (Sharma and Kohli, 2014). The policy also emphasized upon the close relationship between the tribal population and the forest (Saxena, 1996). In tune with the nation's forest policy, the programmes aims at enhancing and improving the forest and tree cover of the country thereby enhancing the quantum of forest ecosystem services that flow to the local communities. The services include fuelwood, timber, fodder, NTFP and also carbon sequestration. It is underlined that in the Indian context, carbon service from forest and plantations is one of the co-benefits and not the main or the sole benefit. Present initiatives like National Afforestation Programme of the Ministry of Environment, Forest and Climate Change (MoEFCC), together with programmes in sectors like agriculture and rural development are on an average adding or improving 1mha of forest and tree cover annually. This annually adds about 1 million tonne of carbon incrementally, and combined with the accretion of biomass in our managed forests, protected areas, and in tree cover outside the government forests, the total carbon service at present is estimated at 138 mt CO₂ eq. every year (Kishwan et al., 2009). The cost of the projected reforestation and afforestation activities contributing in mitigation and adaptation is estimated at Rs. 50,000.00 million annually for the 12th Five Year Plan, or Rs. 2,50,000 million for the entire Five Year Plan (Planning Commission, 2011).

3.2 Joint Forest Management

In 1990 India initiated a very successful programme involving local communities for forest protection and management. The concept of Joint Forest Management (JFM) recognizes the share of the protecting communities over forest produce. The local communities and the State Forest Department jointly plan and implement forest regeneration and development programmes, and the communities are rewarded with substantial share in forest produce in return for their efforts in protection and management of forests. JFM functions through its three systems- the forest supporting system, life supporting system and JFM supporting system (Paulraj, 2012). So far, more than 1,12,816 JFM committees have been formed covering about 25 million ha of forest area (ICFRE, 2010). JFM has enabled protection and regeneration of existing forests, and raising of forest plantations, which is contributing in conservation of existing forests as also the carbon stocks. The total area under JFM is now comparable to the areas managed under national parks and sanctuaries. This approach matches well with the objectives of National Environment Policy, 2006 which, *inter-alia*, emphasizes the identification of climate change impacts on forests, and the need to internalize the mitigation and adaptation measures with respect to forest management (Rawat and Kishwan, 2008).

The concept of JFM in India is a step towards the conversion of low-productivity forests to productive forests. Improving the stocking of poorly stocked forests will also in turn increase carbon stocks. Currently, JFM covers approximately 29.8% of the total forest area of the country (ICFRE, 2010). Over the years, the involvement of the local communities in the management of forests has increased manifold due to setting up of JFMCs in many parts of India. In India, 59.31% forest land is administered by the government and 28.5% is designated for use by communities and indigenous groups (RRI, 2011). The implementation of JFM programme aims to improve quality of forests besides improving the economic status of local people involved in the protection and management of forests.

NATIONAL ACTION PLAN ON CLIMATE CHANGE AND STATE ACTION PLANS ON CLIMATE CHANGE

1. National Action Plan on Climate Change

Launched in 2008, India's National Action Plan on Climate Change (NAPCC) identifies a number of measures that simultaneously advance the country's development and climate change related objectives of adaptation and mitigation.

The implementation of the NAPCC is designed to take place through eight National Missions, which form the core of the National Action Plan and incorporate multi-pronged, long-term and integrated strategies for achieving India's key goals in the context of climate change. The eight National Missions under NAPCC are given in the Box 2. National Mission for a Green India also called Green India Mission is one of the key missions under NAPCC dealing with mitigation and adaptation of climate change in the forestry sector (MoEFCC, 2014).

Box 2. National Action Plan on Climate Change: Eight National Missions

- 1. Jawahrlal Nehru National Solar Mission
- 2. National Mission for Enhanced Energy Efficiency
- 3. National Mission on Sustainable Habitat
- 4. National Water Mission
- 5. National Mission for Sustainable Agriculture
- 6. National Mission for Sustaining the Himalayan Ecosystem
- 7. National Mission for a Green India
- 8. National Mission on Strategic Knowledge for Climate Change.

2. National Mission for a Green India

The National Mission for a Green India (also referred to as Green India Mission or GIM) recognizes that climate change phenomena will seriously affect and alter the distribution, type and quality of natural resources of the country and the associated livelihoods of the people. GIM acknowledges the influences that the forestry sector has on environmental amelioration through climate mitigation, food security, water security, biodiversity conservation and livelihood security of forest dependent communities (MoEF, 2010).

GIM puts the "greening" in the context of climate change adaptation and mitigation, meant to enhance ecosystem services like carbon sequestration and storage (in forests and other ecosystems), hydrological services and biodiversity; along with provisioning services like fuel, fodder, small timber and NTFP.

Key innovations under GIM:

- (i) Focus on quality of forests: Primary focus on improving density of forest cover
- (ii) Focus on ecosystem services: Emphasis on biodiversity, water and improved biomass, carbon sequestration as co-benefit, addressing ecosystems like grasslands, wetlands, urban and peri-urban
- (iii) Focus on democratic decentralization: Gram Sabha (Village level institution) as overarching institution

- to facilitate implementation of the Mission activities at village level, nested as Polycentric Approach (not one size fits all)
- (iv) Creating a new cadre of Community Youth as Foresters: Build a skilled cadre of young "community foresters" from scheduled tribes and other forest dwelling communities
- (v) Adoption of Landscape-based Approach: Interventions at scale (5000-6000 hectares) at a time, simultaneous treatment of forest and non forest areas and addressing key drivers of degradation
- (vi) Reform Agenda as conditionality

The Green India Mission aims at responding to climate change by a combination of adaptation and mitigation measures, which would help in (i) enhancing carbon sinks in sustainably managed forests and other ecosystems; (ii) adaptation of vulnerable species/ecosystems to the changing climate; and (iii) adaptation of forest dependent local communities in the face of climatic variability.

Carbon Mitigation Potential of GIM: Ravindranath and Murthy (2010) made a detailed assessment of mitigation potential of Green India Mission by determining various factors such as consideration of:

- □ Different carbon pools (aboveground and belowground biomass, soil organic carbon and dead organic matter)
- □ Rates of change in the carbon pools
- ☐ Transfer and dynamics of different carbon pools
- ☐ Harvest and extraction of timber, fuelwood, etc
- ☐ Initial stock of different carbon pools
- □ Species-mix and density
- ☐ Phasing of the activity and area planted during different years

Table 4.1 provides the estimates of incremental and cumulative mitigation potential for the different interventions. The mitigation potential was estimated using the COMAP model, as done by other studies (Sathaye *et al.*, 1995, Ravindranath *et al.*, 2001, Ravindranath *et al.*, 2008). The growth rates for aboveground biomass and soil organic carbon were obtained from the literature and belowground biomass was computed using the IPCC default value of 0.26.

The incremental annual mitigation potential of only the GIM interventions was estimated to be 148.7 Mt CO₂ for 2020. This alone has the potential to offset 6.4% of the national GHG emissions projected for 2020

(Ravindranath and Murthy, 2010). GIM provides an incomplete estimate (e.g. excluding soil carbon) of the mitigation offset potential of only 1.5% of the projected GHG emissions. If the mitigation potential of the ongoing afforestation programme (of 1.2-1.3 million ha, annually) under different schemes of the Government of India, State Governments and externally aided agencies is considered based on a earlier study (Ravindranath and Ostwald, 2008), the total mitigation potential (ongoing afforestation + GIM interventions) is estimated to be 246 Mt CO_2 , with a potential to offset 10.5% of the projected national GHG emissions. These estimates exclude any emissions resulting from harvest and disturbance. Thus the forest sector can significantly contribute to reducing GHG emissions in India in the coming years.

Table 4.1. Incremental and cumulative mitigation potential (Mt CO₂) of different forests

Intervention/ sub-mission	Area (mha)	Incremental annual mitigation potential 2020 (Mt CO ₂)	Incremental cumulative mitigation potential 2010-20 (Mt CO ₂)	Incremental cumulative mitigation potential 2010-2030 (Mt CO ₂)
Moderately dense forests (MDF)	2.0	21.7	14.4	343.1
Degraded and open forests (D/O)	4.0	70.1	369.1	1107.4
Scrub/grassland ecosystem (S/G)	2.0	20.2	106.2	318.6
Mangrove and wetland ecosystem (M-W)	0.2	24.2	127.6	382.8
Agro-forerstry and social forestry including urban forestry + corridors (AF-SF-UF-C)	1.8	12.5	65.9	197.6
Total	10.0	148.7	783.1	2349.4

Carbon pools considered: Aboveground and below ground biomass, soil, and litter pools; Area to be planted; 10mha phased equally over 10 years, starting 2011. Growth rates: MDF: 2.5 t/ha/yr, S/G: 1.51 t/ha/yr; M-W: 3.2 t/ha/yr, AF-SF-UF-C: 0.84 t/ha/yr (Source: Ravindranath and Murthy, 2010)

The Report of Sub-Group on Climate Change of 12th Five Year Plan (Planning Commission, 2011) projected mitigation in the forest sector as follows:

- (I) Business-as-usual scenario: According to Ravindranath et al. (2008), assuming that the current trend in area under forests and afforestation continues, the area under forest cover is projected to reach 72 million ha by 2030. The estimate of carbon stock in Indian forests in both soil and vegetation is estimated to range from 8.58 to 9.57 GtC. The carbon stock in existing forests is projected to be nearly stable over the next 25 year period at 8.79 GtC. However, if the current rate of afforestation and reforestation is assumed to continue, the carbon stock could increase from 8.79 GtC in 2006 to 9.75 GtC by 2030, i.e., an increase of 11%. The estimates made in this study do not include forest degradation and loss of carbon stocks due to biomass extraction, fire, grazing and other disturbances.
- (ii) Greening India Mission scenario: The incremental annual mitigation potential of the Mission interventions is estimated to be about 55 MtCO₂ in the year 2020, using moderate to conservative carbon accumulation rates.
- (iii) 33% Forest cover scenario: Government of India has set a long term goal of bringing 33% of geographic area under forest cover. The mitigation potential of afforestation policy in India for the forest sector over the

period of 2010–2030 was assessed (Chaturvedi *et al.*, 2010; Planning Commission, 2011) considering two scenarios: (a) Rapid afforestation rate scenario-2020 (achieving the 33% goal by 2020) and (b) a moderate afforestation rate scenario-2030 (achieving the 33% goal by 2030). The projected afforestation could mitigate 5.2 GtCO₂ under scenario-2020 over the 2010– 2030 period, compared with 3.96 GtCO₂ under scenario-2030, over the same period. The aggregate mitigation potential in scenario-2020 is estimated to be approximately 3.2 GtCO₂ over the baseline, while in scenario-2030, the overall increase in mitigation potential is approximately 1.8 GtCO₂ which shows that rapid afforestation under scenario-2020 will lead to an incremental 1.4 GtCO₂ mitigation potential over scenario-2030.

The Mission objectives, targets, time lines, budgetary requirements and achievements to date for other National Missions under NAPCC are given below (MoEF CC, 2014):

3. Jawaharlal Nehru National Solar Mission

Mission Objective: To establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible.

Mission Targets and Timeline: The Mission has adopted a three phase approach.

The first phase (2010-2013) was designed to focus on capturing the low-hanging options in solar thermal; promoting off grid systems to serve populations without access to commercial energy and modest capacity addition in grid-based systems. In the second (2013-2017) and third (2017-2022) phases, capacity will be aggressively ramped up to create conditions for scaled-up and competitive solar energy penetration in the country (MoEFCC, 2014).

To achieve this, the mission targets that by year 2022:

- ☐ Create an enabling policy framework for the deployment of 20,000 MW of solar power
- ☐ Create favorable conditions for solar manufacturing capability, particularly solar thermal for indigenous production and market leadership
- ☐ Promote programmes for off grid applications reaching 2,000 MW

Synergy with Green India Mission: Introduction of improved cooking stoves can help in substantiating objectives of the National Mission for Enhanced Energy Efficiency. Fuelwood still remains the largest source of energy for rural households in India. The Planning Commission (2014) projected that avoided emissions from excessive use of fuelwood in cooking stoves in rural areas (800 million people or 160 million families) can significantly contribute to increase in forest carbon stocks by replacing ordinary cooking stoves with

improved fuel efficient ones. Carbon seguestration is enhanced because of fuelwood saved due to use of improved cooking stoves. Presuming that 75 percent of the fuel biomass used in rural areas comes from forests, and also that cooking stoves can reduce fuelwood consumption by about 30 percent by improving energy efficiency, each rural family using fuelwood for energy can save about 300 kg of fuelwood annually, and consequently will not extract that much quantity of biomass from the forests. Since the forests from where the fuelwood is extracted are usually degraded, and still growing, the entire quantum of fuelwood saved would result in equal amount of biomass left intact in the forests, thereby offsetting corresponding amount of emissions equal to 58.2 mtCO₂eq. (160*0.75*0.3*0.4=14.4 mtC*44/12=52.8 mtCO₂eq). Popularizing improved cook stoves in rural India will reduce the fuelwood consumption and will address the problem of forest degradation in the forests located in the vicinity of forest fringe villages (Planning Commission, 2014).

5. National Mission on Sustainable Habitat

Mission Objective: To promote sustainability of habitats though improvements in energy efficiency in buildings, urban planning, improved management of solid and liquid waste including recycling and power generation, modal shift towards public transport and conservation.

To achieve its objective, the mission targets are:

- Extension of the Energy Conservation Building Code, which addresses the design of new and large commercial buildings to optimize their energy demand. Incentives will be provided for re-tooling existing building stock
- Better urban planning and modal shift to public transport by making long term transport plans to facilitate the growth of medium and small cities in such a way that ensures efficient and convenient public transport
- Recycling of material and urban waste management under which a special area of focus will be development of technology for producing power from waste. The mission will include a major R&D programme, focusing on bio-chemical conversion, wastewater use, sewage utilization and recycling options wherever possible

The mission includes timelines for all the strategies and sub-components of each strategy.

Budgetary Requirements and Allocation: The total funding requirement assessed for the 12th five year plan period (2012-2017) is ₹ 950 crore (approx. USD 153 million), which is to be met from existing budget of the Jawaharlal Nehru National Urban Renewable Mission.

Key achievements to date:

- Energy Conservation Building Code 2007 made mandatory for new as well as old buildings; incorporated in Central Public Works Department general specification for electrical works in 2013
- More than 50 capacity building programmes in various stages of implementation
- Long term transport plan for cities prepared
- Sanctioned 760 water supply projects at an estimated cost of ₹35,650 crore (approx.USD5.75 billion) under on going programmes such as JNNURM

Synergy with Green India Mission: Urbanization is taking place at a fast rate in India. Population residing in urban areas in India, according to 1901 census, was 11.4% (Singh, 1978). This increased to 28.53% according to 2001 census (Datta, 2006), and crossing 30% as per 2011 census, standing at 31.16% (Roy, 2012). According to a survey by UN State of the World Population Report in 2007, by 2030, 40.76% of country's

population is expected to reside in urban areas (Hindustan Times, 2007).

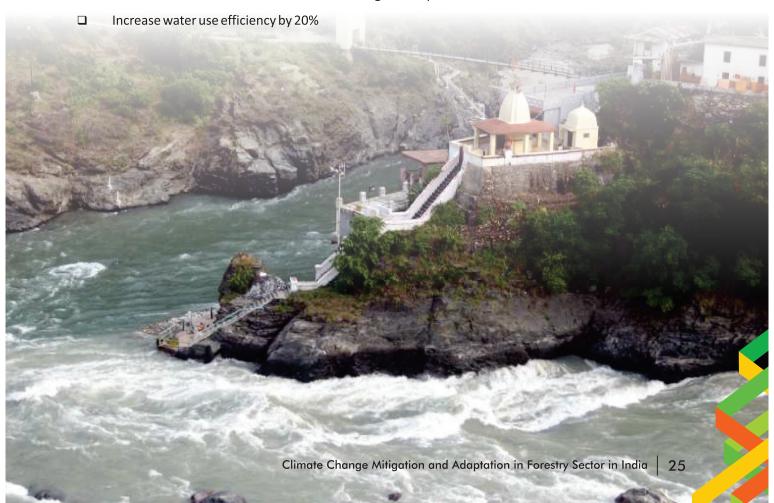
Urbanization is a logical and well anticipated consequence along with the development of cities. The role of urban forests in ameliorating urban habitats and improving quality of life is significant. Planting trees around the city can be a way of increasing albedo and decreasing the urban heat island effect. Trees in urban systems provide a variety of ecosystem services including biodiversity conservation, removal of atmospheric pollutants, oxygen generation, noise reduction, mitigation of urban heat island effect, microclimate regulation, stabilization of soil, groundwater recharge, prevention of soil erosion and carbon sequestration. Urban forestry has to be planned, integrated and systematic. The primary objective of the GIM is to increase forest/tree cover on 5 million ha of forest/non-forest lands and improved quality of forest cover on another 5 million ha (a total of 10 million ha). Under greening of non-forest cover, the urban forestry programmes with active participation and collaboration from government departments, educational institutions, municipal bodies and local residents may also be undertaken for greening of the urban cities under the National Mission on Sustainable Habitat.

6. National Water Mission

Mission Objective: To conserve water, minimize wastage and ensure equitable distribution both across and within states through integrated water resources development and management.

Mission Targets and Timeline: To achieve its objective, the mission targets are:

- Development of comprehensive water data base in public domain and assessment of impact of climate change on water resources
- ☐ Promotion of citizen and state actions for water conservation, augmentation and preservation
- ☐ Focused attention to vulnerable areas including over-exploited areas



☐ Promotion of basin level integrated water Resources management

Budgetary Requirements and Allocations : The Mission requires budgetary support of ₹ 1,08,000 crore (approx.USD17.4 billion) up to the end of 12th Five Year Plan period (2011-2017). Proposals for ₹ 13,034 crore (approx.USD2.1 billion) have been approved.

Key achievements to date:

Revised National Water Policy (2012) adopted by National Water Resources Council
Created 1,082 new ground water monitoring wells

Several capacity building and training programmes are underway

Synergy with Green India Mission: Forests can be managed to enhance freshwater supplies, but as a component of comprehensive and multifaceted water management programmes. The water yield of urban watersheds can be augmented with correct matching of species and site specially planting of tree species with low consumptive use. Plantations (afforestation/reforestation/agroforestry systems) need to be developed for upland watersheds in order to capture the hydrological benefits of forests, while enhancing food and natural resource production for the rural poor.

Better management of forests and water resources to improve human welfare requires more than just technical knowledge. While technical information provides a foundation for assessing upstream-downstream linkages and carrying out economic analyses, transforming such information into management practices requires the effective participation of stakeholders in order to develop a consensus and provide incentives for implementation (Eckman *et al.*, 2000). A policy environment must be created that supports the integration of land and water management.

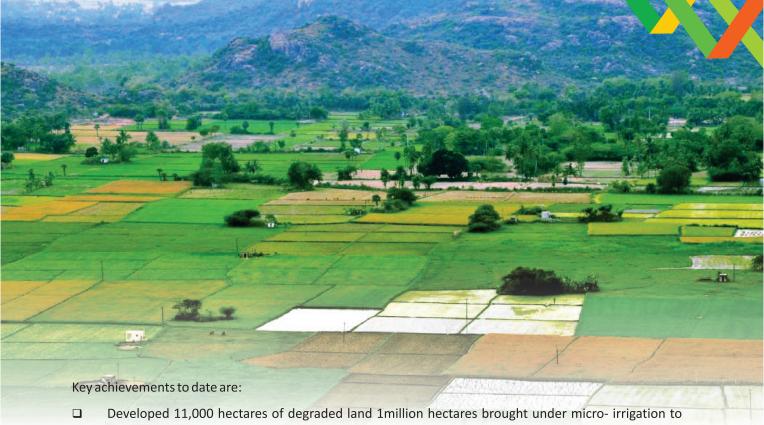
Forest management and other watershed improvements to protect and manage freshwater require additional financial resources these can be met from the Mission budget. Under the water mission forestry interventions has the potential to mitigate the economic damage caused by floods and sediment delivery through forest management in uplands, riparian areas and flood plains. A healthy upland and riparian forests can maintain low levels of sediment delivery to rivers, lakes and reservoirs and other water sources.

7. National Mission for Sustainable Agriculture

Mission Objective: To transform agriculture into an ecologically sustainable climate resilient production system while at the same time, exploiting its fullest potential and thereby ensuring food security, equitable access to food resources, enhancing livelihood opportunities and contributing to economic stability at the national level.

To achieve its objective, the mission will work on the following major programme components or activities:

- ☐ Rainfed Area Development: Adopt an area based approach for development and conservation of natural resources along with farming systems
- On-Farm Water Management: Enhance water use efficiency by promoting efficient on-farm water management technologies and equipment
- □ Soil Health Management: Promote location as well as crop specific sustainable soil health management
- □ Climate Change and Sustainable Agriculture: Monitoring, Modeling and Networking: Creation and bidirectional (farmers to research institutions and vice versa). Dissemination of climate change related information and knowledge



- promote water efficiency
- Created 5.4 million metric tonne agricultural storage capacity

Budgetary Requirements and Allocations Implementation Status: The mission requires budgetary support of ₹1,08,000 crore (approx.USD17.4billion) up to the end of 12th Five Year Plan period (2011-2017). Proposals for ₹13,034 crore (approx.USD2.1 billion) have been approved.

National Mission for Sustaining the Himalayan Ecosystem

Mission Objective: To evolve management measures for sustaining and safeguarding the Himalayan glaciers and mountain ecosystem and attempt to address key issues namely impacts of climate change on the Himalayan glaciers, biodiversity, wildlife conservation and livelihood of traditional knowledge societies.

To achieve its objective, the mission targets (selected) are:

- Creation of a fund (approx. ₹ 1,650 crore or USD 266 million) for developing capacities for Sustaining Himalayan Ecosystem
- Establishment of a State-of-the-Art National Centre for Himalayan Glaciology
- Identification and networking of all knowledge institutions in the region which possess the institutional capacity for studies on Himalayan ecosystems
- Establishment of about 10 new centers in existing institutions in areas of knowledge gaps complete with special mechanisms and tools to create knowledge capacity for sustaining Himalayan ecosystems
- Annual status reports on the health of various sub-components of the Himalayan ecosystems and biannual advisories to the Himalayan Sustainable Development Forum through state councils for climate change in the Indian Himalayan states for actions for implementation
- Standardization of data collection systems for inter-operability and mapping of natural resource wealth systems

- ☐ Identification and training of about 100 experts and specialists in areas relevant to sustaining the Himalayan ecosystem including about 25 glaciologists
- ☐ Conduct 25 programmes on capacity building for linking innovations from traditional and modern knowledge systems
- Establishment of an observational network for monitoring and fore warning of changes in the ecosystems of the Himalayan region

Budgetary Requirements and Allocations: The total funding requirement for 2010 to 2017 is ₹ 1,695 crore (approx. USD 273 million). Proposals for ₹ 500 crore (approx. USD 81 million) have been approved.

Key achievements to date are:

- Established 6 new centers relevant to climate change in existing institutions in Himalayan states
- ☐ Created an observational network to monitor the health of the Himalayan ecosystem
- ☐ Several capacity building and training programmes underway

Synergy with Green India Mission: The Indian Himalayan Region (IHR), which accounts for around 70% of the Himalayan biodiversity hotspot, spreads across a land area of 5,30,000 km², comprising 16.2% of India's geographical area. The IHR has rich forest cover, feeds the sub continent's perennial rivers that are a source of drinking water, irrigation and hydropower, and conserves important elements of our rich biodiversity. Managing the Himalayan ecosystem sustainably is critical not only for preserving its pristine beauty and spectacular landscapes, but also for ensuring the ecological security of the entire Indian sub-continent (MoEF, 2010).

The guidelines issued for National Mission on Sustainable Himalayan Ecosystems (NMSHE) document cover a wide variety of issues – including urbanization, tourism, water security, energy, forest management and infrastructure – all of which are highly pertinent as the Himalayan region faces new and increased challenges and pressures (GBPIHED, 2010).

The Indian Himalayan Region is ecologically very important for its high forest cover. More than 41.5 % of its geographical area is under forest cover representing one-third of the total forest cover in India and nearly half (47%) of the "very good" forest cover category of the country (ISFR, 2013). These forests generate a plethora of goods and services (Singh and Singh, 1992). The Himalaya with its vast green cover acts as a 'sink'

for carbon dioxide, an important ecosystem service (Singh, 2002). Under the National Mission for Sustaining the Himalayan Ecosystem, two thirds of the geographic area of the IHR is targeted to be under forest cover, with the local communities playing an important part in its maintenance, payments for the ecosystem services of the standing forests of this region can be one such measure to involve the local communities in the conservation and adaptation efforts (GBPIHED, 2010). Dovetailing mission objectives of NMSHE and GIM can synergized for effective implementation of these two important National Missions under NAPCC where forestry has important role to play for mitigation and adaptation to climate change.

National Mission on Strategic Knowledge for Climate Change 9.

Mission Objective: To identify the challenges and the responses to climate change through research and technology development and ensure funding of high quality and focused research into various aspects of climate change.

To achieve its objective, the mission targets are:

affected by climate change Leverage development of suitable technologies for adaptation and mitigation of climate change under various missions		Form well designed knowledge networks with a well structured framework for harmonization, interoperability, sharing and Exchange of data of relevance to climate change and responses
affected by climate change Leverage development of suitable technologies for adaptation and mitigation of climate change under various missions Assist other agencies engaged in the implementation of the National Action Plan on Climate Change and supporting the actions under the other Missions, as and if necessary		Enhance the research capability in climate science
under various missions Assist other agencies engaged in the implementation of the National Action Plan on Climate Change and supporting the actions under the other Missions, as and if necessary		Position a technology watch system for key sectors related to economic development, likely to be affected by climate change
and supporting the actions under the other Missions, as and if necessary		Leverage development of suitable technologies for adaptation and mitigation of climate change under various missions
Key achievements to date are:		Assist other agencies engaged in the implementation of the National Action Plan on Climate Change and supporting the actions under the other Missions, as and if necessary
	Key a	chievements to date are:

- Established 12 thematic knowledge networks
- Developed 3 regional climate models
- Trained 75 high quality climate change professionals

Budgetary Requirements and Allocations: The total funding requirement for the 12th five year plan period (2012-2017) is ₹2,500 crore (approx. USD 403 million). The allocations to undertake these mission activities will be met out of the budget allocation of the existing scheme of the Department of Science and Technology, Government of India.

Synergy with Green India Mission: Climate is probably the most important determinant of vegetation patterns globally, and has significant influence on the distribution, structure and ecology of forests. Several climate-vegetation studies have shown that certain climatic regimes are associated with particular plant communities or functional types. It is, therefore, logical to assume that changes in climate would alter the configuration of forest ecosystems. The projected climate change is likely to impact existing forest ecosystems, biodiversity and biomass production. Many of the impacts of climate change on forests and other natural ecosystems (mangroves, coral reefs, wetlands, montane grasslands) such as loss of biodiversity could be irreversible. There is still large uncertainty with respect to projections of regional climate change, vegetation response models and its linkage to socio-economic impacts.

The National Mission on Strategic Knowledge on Climate Change (NMSKCC) can also include research on various aspects of forests and climate change. Some of the pertinent issues that can be addressed by the

NMSKCC are as follows:

Modelling studies and research: Modelling studies and research are important for predicting general trends related to climate change in respect of forest ecosystems, but short term and long term research and studies on behaviour of individual plant species as also of plant communities are equally important to understand, plan, develop and implement strategies to minimize adverse impact of climate change on forests and other vegetation. Such research would also be useful in fine-tuning and even validating vegetation and carbon dynamics models that are developed in short term. Similarly, research to study potential of different species, forest type groups and vegetation communities to sequester carbon would be needed to plan and implement strategies capable of capturing optimum carbon from atmosphere.

Thus, both short term and long term research would be essential to optimally utilise potential of forestry sector in climate change mitigation and adaptation. Observations carried out in preservation plots laid out in different forest types and ecosystems across the country could be gainfully integrated with the research projects and studies aimed at climate change mitigation and adaptation.

Research on adaptation and vulnerability: Currently, there is very little research on adaptation. There is a need for initiating research on developing and evaluating adaptation practices and strategies to enhance the resilience of the forest ecosystems. India has a large afforestation programme and a very ambitious Green India Mission under NAPCC and the National Forest Policy of India, 1952 which aims to bring 33 percent of land under forest cover. Thus, there is a need to reduce the vulnerability of the afforestation programmes to projected climate change. Appropriate adaptation practices may have to be developed and incorporated into afforestation/reforestation programmes.

10. State Action Plans on Climate Change

Consequent upon release of National Action Plan on Climate Change, the Prime Minister's Council on Climate Change called upon States to prepare their State Action Plans on Climate Change (SAPCCs). Ministry of Environment, Forest and Climate Change, Government of India, in coordination with international agencies developed common generic framework to provide guidance to the states for preparation of SAPCC. The central government has provided technical and financial support to the states for finalizing their SAPCCs. MoEF CC requested states to priotitise adaptation actions vis-à-vis state priorities and local level impacts. The central government proposed the 'Climate Change Action Programme' during 2011-12 to support implementation of SAPCCs. Other sources of funding for implementation of SAPCCs include line Ministries, State Budget, Multilateral and Bilateral Funding and Finance Commission.

Following State Action Plans on Climate Change of following States have been endorsed by National Steering Committee on Climate Change:

1. Andaman & Nicobar	6. Jammu & Kashmir	11. Mizoram	16. Rajasthan
2. Andhra Pradesh	7. Lakshadweep	12. Nagaland	17. Sikkim
3. Arunachal Pradesh	8. Madhya Pradesh	13. Odisha	18. Uttarakhand
4. Assam	9. Manipur	14. Puducherry	19. West Bengal
5. Chhattisgarh	10. Meghalaya	15. Punjab	20. Tripura

State Action Plans on Climate Change of Haryana, Jharkhand, and Karnataka have been considered by Expert Committee on Climate Change. Forest and climate change mitigation related activities under various State Action Plans on climate change have been given in Table 4.2.

Table 4.2. State Action Plans on Climate Change

S. No.	State	Proposed Forestry Action		
1.	Andaman & Nicobar Islands	 Protection of existing forest areas Increasing density of the open forests Phasing out of monoculture plantations and conversion into secondary forests Improved utilization of timber in Government's saw mills Enhancing efficiency of small wood and NTFP based Industries 		
2.	Chhattisgarh	 Sustainable livelihoods through JFM and NTFPs Lac development programme Construction of culverts on forest paths Supply/distribution of seedlings Hariyali Prasar Yojana River bank plantation programme Regeneration of degraded bamboo forests Ground water conservation Plantation along highways, district, and rural road 		
3.	Puducherry	 Enhancing productivity through introduction of genetically superior seeds Promotion of farm forestry and agroforestry Consolidation and protection of forests Identification and propagation of adaptive species through modern nurseries. Study on REDD plus and REDD plus feasibility for afforestation Protection of mangrove forests Monitoring critical faunal habitats to assess impact of climate change 		
4.	Meghalaya	 Assessment of biodiversity and preparation of micro plans for conservation Assessment of afforestation-reforestation for emission reduction and sustainable livelihood, institutional capacity building, implementation and evaluation for forest development and management for climate change Undertaking studies and investment promotion of NTFP and indigenous forest resources for adaptation of climate change Undertaking study on valuation of forest resources and Monitoring of carbon stock and biodiversity at regular intervals Study on climate change impact on forest cover and indicative adaptation measures Site identification and survey demarcation and PRA for community forest land 		

Adaptive species identification for effective establishment of tissue culture and permanents.	-	
Ecotourism promotion for biodiversity p livelihood through Pre-investment feasibili pilot implementation in two region		
·	 Increase plantation and ecological restoration on non-forest land through different plantation and soil conservation programme 	
	Assess additional threats to biodiversity and wildlife and mitigation of man-animal conflicts due to Jhum cultivation in elephant corridors	
Encourage continuance of community fore towards sustainable livelihood options	sts by way of giving inputs	
Work to establish new systems to support for through establishment of ENVIS Centre	or public awareness building	
5. Lakshadweep • Reclamation and regeneration of vegetation ponds	on in and around lakes and	
Establishing medicinal plant plot and herbal	garden	
Establishment of botanical garden		
Mangrove restoration and regeneration		
Establishment of nursery		
Habitat restoration of wet lands and lagoon		
Establishing children's park		
Coastal plantation		
Distribution of fruit plants	Distribution of fruit plants	
 Jammu and Kashmir Capacity building and awareness for all level Gene bank development for climate adapta 		
Eco-restoration through afforestation and c restoration plan	limate oriented eco-	
Phenological studies of forestry and other t	ree Species	
Flora and fauna vulnerability study	Flora and fauna vulnerability study	
Studies of carbon influxes/ out fluxes of var and their role in carbon sequestration	 Studies of carbon influxes/ out fluxes of various forest types / trees and their role in carbon sequestration 	
Study on per capita fuelwood consumption	and alternate livelihood	
Study on soil organic carbon of forest area		
Climate impact study in undisturbed/ protected.	ed forest areas	

		E-green portal with georeference	
		Nursery development for climate adaptable species	
		REDD plus feasibility study for carbon sequestration	
		Study of climate change impact on wild life species	
		Climate change impacts on undisturbed forest area like national parks	
		Studies of impact of managed watershed under different management system on sustained water availability	
7.	Jharkhand	Research and development- Research to ascertain impact of climate change on forests	
		Development of climate change resilient forest management plans	
		Rural energy management	
		Increasing economic efficiency of the forest resources	
		Out of forest tree cover enhancement	
		Forest biodiversity strategies management	
		Capacity building/ Awareness generation	
		Institutional arrangement on climate change and mitigation	
		Action to reduce damage to forest property from mining activities	
		Exploration of carbon mitigation options	
		Forest fire strategies management	
8.	Karnataka	Raising of forest plantations in non-forest land unfit for agriculture	
		Raising of farm forestry plantations by encouraging farmers	
		Monitoring of carbon stocks in collaboration with Indian Institute of Science and other universities	
		 Devise strategies to identify market-linked opportunities for development of robust carbon sinks as well as increasing income for local communities 	
		Develop a sustainable timber harvest plan along with reforestation schemes and revenue plantations	
		Develop a policy to protect existing forest stocks as carbon sinks through stronger conservation and community participation	
		Undertake reforestation/ afforestation in degraded areas	
		Rigid protection of forest through strengthening personnel and infra- structure	
		Systematic recording of unplanned extraction of fuelwood, fodder, non-timber forest products (NTFP), green manure etc	

		 Enhance the capacity of communities to manage and store firewood and fodder under ambient conditions. Provide institutional credit and create alternative market-based market options Actions involving gradual loss of green cover in urban areas
9.	Himachal Pradesh	 Bio-carbon clean development mechanism National Bamboo Mission Green India Mission Programme through National Medicinal Plant Board
10.	Arunachal Pradesh	 To increase more forest cover and eco-restoration of degraded forests Social forestry programmes through distribution of seedlings and creation of Apnavan through involvement of people
		 Development of non timber forest produce Strengthening of forest protection measures including protection against fire
		 Intensification of scientific management of the forests for sustainable optimum yield
		 To improve and extend protected area network for conservation, protection and development of biodiversity and wild life and also to involve communities in wildlife conservation in high altitude areas through setting up community conserved area and promotion of eco- tourism
11.	Sikkim	To increase substantially the forest/tree cover in the state through massive afforestation, social forestry programmes
12.	Assam	To prevent the encroachment of forest areas and consolidating and demarcating reserve forest boundaries
		 Sustainable management of forests with the help of local communities Development of non timber forest product potential of the state
13.	Haryana	 Adaptation programmes for the short rotation species, sustainable harvesting of timber and non-timber products, enhancement in field of agro forestry and social forestry with multiple species and incorporation of anticipatory planting of species
		 Plantation of degraded forest land Distribution of fuel efficient cooking stoves for rural house hold
		 Projected annual increment of CO₂: 10.31 million tonnes
14.	Madhya Pradesh	Development of Sustainable Forest Management Plans for different forest types in view of climate change

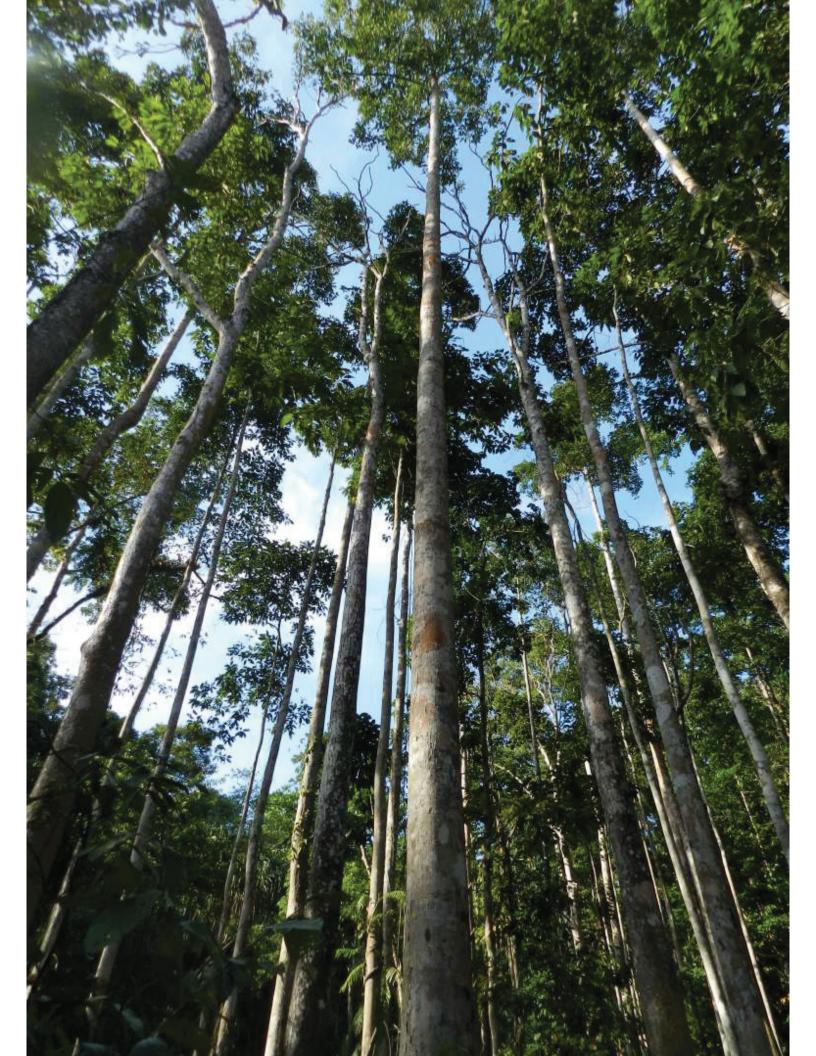
		 Enhancement of forest conservation, afforestation/ reforestation activities through viable models 		
		Promote research to understand the impact of climate change on forest ecosystem and vulnerability mapping of forests		
15.	Manipur	Research on the non-cash contribution of forests		
		 Sustainable management of forests by implementation of working plans. 		
		 Protection of state forest resources and creation of State Forest Protection Force 		
		Ensuring long term forest rights and tenure		
16.	West Bengal	Enhancement of spring recharge and ground water recharge in forest areas		
		Enhancement the quality of moderately dense forest, open forest and degraded forests		
		Connecting the fragmented forests with 'Canopy Corridors' and 'skyways' to assist species migration		
		Enhancement of fire prevention and fire management		
17.	Andhra Pradesh	 Strengthening of protection and conservation To check soil erosion and conserve moisture. 		
		Coordination among communities by forming suitable action groups within the community, finance in form of funds, land and manpower would be needed		
		Strengthening of the Integrated Afforestation & Eco-development Project to check forest degradation and loss of biodiversity, promote ecological restoration		
		Environmental conservation and eco-development, promote shelter belt plantations in coastal areas to reduce damage from cyclones		
		Revitalize community based initiative like Joint Forest Management		
		Forest fire management		
		Enhancement of public and private investments for raising plantations for enhancing the cover and density of forests		
		Effective implementation of Protected Area System under Wildlife Conservation Act and National Biodiversity Conservation Act, 2002		
18.	Rajasthan	Afforestation/Reforestation measures for promoting adaptation and carbon sequestration		
		Sequential restoration of dunes in Thar Desert		

19.	Uttarakhand	 Increasing the existing area under forests and trees and improving the quality and density of the degraded forests 		
		 Enhancing natural resources and livelihood options of the vulnerable sections 		
		Soil and water conservation, biodiversity conservation and fires management		
20.	Punjab	 Add at least 3.13% more area under forest and tree cover to the existing area bringing the total area under forest and tree cover to 10% of the total geographical area of Punjab by 2022 		
		Enhance forest density over the designated Forest Area of the state which is mainly concentrated in the Shivaliks		
		Undertake capacity building activities to achieve the goals of Punjab Green Mission on forests		
21.	Odisha	Increasing reforestation/afforestation activities in degraded forest areas		
		Protecting existing forest stocks to act as carbon sink with stronger conservation		
		Increasing planting on non-forest land, trees as barriers to storm and cyclone impacts in coastal zones		
		Increasing and protecting existing mangrove cover along the coast		
		Improving tree planting and forest management to integrate with watersheds management		
		Capacity building of <i>Panchayati Raj</i> Institutions/communities/JFM institutions to adapt to climate change		
		Monitoring carbon stock and biodiversity		
22.	Nagaland	Convert 25% of total jhum area to secondary forest		
		Protecting existing forests/Conserving existing carbon pool		
		Afforestation of degraded area and Jhum area		
		Habitat improvement		
		Energy plantation (fuel and fodder)		
		Vegetative measures, hedgerows, etc		
23.	Mizoram	Improvement of forest quality and density in degraded lands and abandoned jhum lands		
		Improvement the productivity of bamboo and promotion of local value addition through establishment of market linkages		
		Assessment of climate vulnerability and climate change impacts on state biodiversity and forest resources		

- Undertaking studies on climate change impacts on NTFP productivity, investment promotion and indigenous harvesting practices for adaptation of climate change
- Undertaking study on valuation of forest resources (non traded) and climate change impacts on the vulnerable ecosystems
- Restructuring land use policy for jhum cultivation and abitation on notified forest lands
- Policy formulation on transportation subsidy or development of low cost transportation for primary forest products of the state

Source: http://moef.nic.in/ccd-sapcc, Accessed on: 22 September 2014

Forests are a significant part of the carbon cycle. A carbon sink absorbs CO_2 from the atmosphere and stores it as carbon. In the case of a growing forest, carbon storage takes place in the form of wood, other vegetation and soil carbon. Investment in this sector not only increases the carbon sink, but also contributes to the national Gross Domestic Product. The mitigation efforts discussed for increasing the sequestration potential of forests are multi-pronged, involving sustainable management, conservation and improvement in the density of existing forests, facilitation of wood products use management and promoting efficiency in the use of fuel-wood at rural homes. More resource allocation is needed for the Green India Mission and forestry actions envisaged in State Action Plans on Climate Change to enhance the stock of growing forests, and to improve the provisioning of ecosystem goods and services in the country.



REDD PLUS AND OTHER MARKET MECHANISMS FOR FORESTRY SECTOR

Reducing Emissions from Deforestation and forest Degradation (REDD) in developing countries is based on the idea of rewarding projects, programmes for actions that reduce greenhouse gas (GHG) emissions. In many developing countries, REDD has the potential to deliver large cuts in emissions at a low cost within a short time frame and, at the same time, contribute to reducing poverty and sustainable development.

REDD plus stands for Reducing Emissions from Deforestation and forest Degradation including forest conservation, sustainable management of forests and enhancement of forest carbon stocks, and has been adopted by the UNFCCC as a tool for climate change mitigation. Implementation of REDD plus therefore would result in lowering in emission of carbon dioxide and other GHGs from forests on one hand, and enhancement in sequestration of carbon in forests on the other. It appears to be a readily available, practical and cost effective option for reducing GHGs emissions from forests and therefore to mitigate climate change. The co-benefits of REDD plus include enhanced status of biodiversity conservation and ecosystem services that are likely to further augment and strengthen livelihoods of communities and consequently their adaptive capacity to climate change.

To complement actions to reduce emissions from deforestation and degradation, there is a need to further reinforce measures aimed at increasing terrestrial carbon pools by promoting afforestation and reforestation through Clean Development Mechanism (CDM) or other mechanisms, improved forest management, cropland management, agroforestry, grazing land management, and re-vegetation. Promoting tree and forest planting can be a win-win option in many cases, by simultaneously producing ecosystem goods and services for local livelihoods and industries on one hand, and carbon sequestration services for climate change mitigation on the other. There are also possible synergies between carbon sequestration and adaptation measures, e.g., through afforestation of vulnerable areas, watersheds, and rehabilitation of degraded lands.

1.1 India's National REDD-plus strategy

Government of India is in the process of developing its National REDD plus strategy. Ministry of Environment, Forest and Climate Change has prepared a draft national REDD plus Policy and Strategy. The document is web hosted for public comments and will be released soon after taking into account the public comments. Similarly, to facilitate REDD plus at National level among all stakeholders, government has also prepared a 'REDD plus Reference Document'. These documents will serve as a reference/guiding document for implementing REDD plus actions in India. India's draft national REDD plus strategy aims at enhancing and improving the forest and tree cover of the country thereby enhancing the quantum of forest ecosystem services that flow to the local communities. The services include fuelwood, timber, fodder, NTFP and also carbon sequestration. It is underlined that in the Indian context, carbon service from forest and plantations is one of the co-benefits and not the main or the sole benefit.

1.2 Institutional mechanism for REDD plus at national level

The Government of India has established a REDD plus Cell in the Ministry of Environment, Forest and

Climate Change having the task of coordinating and guiding REDD plus related actions at the national level, and to discharge the role of guiding, and collaborating with the State Forest Departments to collect, process and manage all relevant information and data relating to forest carbon accounting. National REDD plus Cell would also guide formulation, development, funding, implementation, monitoring and evaluation of REDD plus activities in the States. The Cell will also assist the Ministry of Environment, Forest and Climate Change and its appropriate agencies in developing and implementing appropriate policies relating to REDD plus implementation in the country.

1.3 Methodological issues of estimation of forest carbon stocks

India's future strategy in this regard is to devolve more and more responsibility on the State Forest Departments to carry out the assessment and estimation of forest carbon stocks (FCS) in conjunction with the biennial exercise of assessment of forest and tree cover (FTC).

This is considered essential to improve the precision level for estimation of FCS as the State Governments are in position to cover more number of sample points. In future, the SFDs can take the responsibility of carrying out the inventories for FTC and FCS by more effectively utilizing the services of their Remote Sensing Centres/ Space Application Centre. Forest Survey of India can act as the source for providing satellite imageries required by the States for the purpose.

1.3.1 Estimation of forest carbon stocks in India

India is among the few countries to regularly use satellite-based remote sensing technology in detecting forest cover changes. The FSI has been assessing the forest cover of the country on a two-year cycle since 1987. Over the years, there have been improvements both in the quality of remote sensing data and the accuracy of interpretation techniques. The 13th biennial cycle has been completed from digital interpretation of data from year 2010-11 and published in 2013 with a minimum mapping unit of 1 ha. FSI is following the tier 2 and tier 3 of IPCC Good Practice Guidance



(methodology) for carbon estimation in forests of India through a combination of remote sensing and ground-based forest carbon inventory. Methodology followed by India for estimation of biomass carbon and soil organic carbon has the potential of being developed and adopted as a general REDD plus methodology for assessing changes in forest carbon stocks at national level in a country over a stipulated period.

1.3.2 National forest reference level

India gives highest priority to fixing of the reference level for carbon stocks in its forest and tree cover with a view to making assessment, monitoring, verification and reporting of baseline forest carbon stocks and incremental forest carbon stocks. Reference level in essence will be a baseline forest carbon stocks position corresponding to a specific year, which may be called as the 'zero year. The 'reference year' would need to be fixed with consensus amongst intra-country stakeholders which would include the Central Government,

State Governments, forest experts and scientists, local community and civil society. It is presumed that the starting point for fixing a forest reference level will be backed by sound logic, time series of scientific historical data, and milestones of relevant legislation and/or policy prescriptions. The reference level would need to be agreed at the technical level, i.e., amongst scientific organizations, and subsequently at the government level involving the Central and the State Governments. Currently Forest Survey of India has been entrusted with working out the reference level for India taking into account national circumstances and rationale.

1.3.3 Local communities and cobenefits of forest ecosystem services

While moving forward towards implementation of REDD plus, participation of local communities with compulsory representation of women would be the central theme. Government of India is committed to ensure that full and adequate incentives from REDD plus go to the local communities as and when

Box 3. Warsaw Framework for REDD plus (COP19)

In order to access results based finance through implementation of national REDD plus strategies was the key outcome of COP19. The set of following seven key decisions is known as Warsaw Framework for REDD plus.

- 1. Work programme on results-based finance; (Decision 9/CP.19)
- Coordination of support for the implementation of activities in relation to mitigation actions in the forest sector by developing countries, including institutional arrangements; (Decision 10/CP.19)
- Modalities for national forest monitoring systems; (Decision 11/CP.19)
- The timing and the frequency of presentations of the summary of information on how all the safeguards are being addressed and respected (Decision 12/CP.19)
- Guidelines and procedures for the technical assessment of submissions from Parties on proposed forest reference emission levels and/or forest reference levels; (Decision 13/CP.19)
- Modalities for measuring, reporting and verifying (MRV); (Decision 14/CP.19)
- Addressing the drivers of deforestation and forest degradation; (Decision 15/CP.19)

these become available. In India's context, the forest will not be managed for 'carbon services' alone, but for all the ecosystem services that are flowing to the local community from the forest. Incentives for carbon services will be an add-on to the benefits that the local communities are already receiving from the forest ecosystems.

1.3.4 Safeguards and safeguards information system

Developing countries are expected to follow safeguards, as mandated various COP decisions with a view to ensure full participation of indigenous peoples, local communities and other stakeholders, and conservation of natural forests and biodiversity in implementing the REDD plus activities. India intends to ensure that all REDD plus incentives available from international sources will flow fully and adequately to the local communities which participate in management or manage the forest resources or are dependent on the forest resources for sustenance of their livelihood. Part of the incentives are expected to be invested in conservation and improvement of the ecosystem services like biodiversity and non-timber forest produce. Local communities would be encouraged to develop micro plans to incorporate such priorities. Various acts and legislations mentioned earlier in the chapter are strong testimony to Government of India's commitment to implement REDD plus safeguards involving participating communities and conservation of its natural forests.

A system for providing information on how safeguards for ensuring participation of local communities, and conservation of natural forests and their ecosystem services will be developed while implementing result based REDD plus actions. In India, tribal communities, forest dwellers and other local communities have always enjoyed legal safeguards to practice their customary rights and traditions. India has had a fairly successful initiative involving local communities for protection and management of government forests. Joint Forest Management ensures a fair share in the forest produce for the protecting communities. Promulgation of the Forest Rights Act (2006) has further strengthened the legal framework in the country for safeguarding the rights of local

Box 4. REDD plus Policy and Definitional Issues

India needs to work upon the definitions of REDD plus activities listed in paragraph 70 of the decision 1/CP.16 to be able to implement the same in its national context and circumstances. Specifically, more insight into understanding the definition of sustainable management of forest (SMF) is required to steer its proper application in forestry mitigation actions in different parts of the country. In ensuring the safeguards for the rights of local communities and indigenous people, involvement of civil society and state forest departments is needed in working out provisions and modalities under the extant Forest Rights Act, and approaches of Joint Forest Management and Community Forest Management.

communities. Also, India will adopt, as appropriate, the modalities of the system as agreed under COP decisions, for providing information on safeguards to the UNFCCC. In order to ensure that relevant safeguards as agreed by the COP decision are respected throughout the implementation of a REDD plus project, the project developer may be asked to give a written commitment that all relevant national laws/legislations/rules/acts/ have been respected and not violated during the implementation of the REDD plus project.



1.4 Initiation of REDD plus pilot projects in India

For the last few years, India's forest cover has been stable, and the successive State of Forest Reports of FSI (ISFR 2009, 2011 and 2013) depict increase in forest and tree cover. Thus, large-scale deforestation is not taking place except in case of shifting cultivation, which is happening mainly in the north-eastern states.

REDD plus pilot projects on conservation, sustainable management of forests (SMF), and enhancement of forest carbon stocks (EFCS). Subject to availability of funding, India intends to launch one REDD plus pilot project each, based on the concept of conservation, SMF and EFCS respectively to understand the intricacies of maintaining baseline forest carbon stocks, forest carbon stocks changes, and forest carbon accounting. These projects will be at locations that cover different forest types and socio-geographic regions of the country. For example, project on conservation can be taken up in the Western Himalayan region comprising States of Uttarakhand, Himachal Pradesh and Jammu and Kashmir, whereas Western Ghats should be suitable to test the concept of SMF. EFCS project can be taken up in any of the States registering increase in forest and tree cover according to latest State of Forest Report published biennially by Forest Survey of India (UNFCCC, 2011b).

1.5 REDD plus pilots in India

A few REDD plus project activities have already been started in India. A brief description of few REDD plus pilots is given below:

(1) Uttarakhand REDD Plus pilot project: Indian Council of Forestry Research and Education (ICFRE) has initiated a REDD plus pilot project in the Van Panchayat (Village Community Forests) of Uttarakhand (India) in the year 2014. Community managed forest like Van Panchayats (Community Forests) in Uttarakhand are example of community control over forests. REDD plus actions are being initiated as demonstration activities

Box 5: CAMPA fund for REDD plus pilot programmes

There is a high potential for the CAMPA funds to complement or contribute to REDD plus funding. CAMPA fund is established to compensate the forestry land in lieu of mining or other development activities that cause deforestation. The CAMPA funds are intended for undertaking compensatory afforestation, assisted natural regeneration, conservation and protection of forests, infrastructure development, wildlife conservation and protection and other related activities. Carbon revenues accrued from these activities could also be shared using similar provision used for other forest produce sales revenues by participating communities. Most of the states have already developed benefit sharing mechanism under JFM for sale of timber and NTFPs (Rawat, 2012).

in these forests. With sizable potential sequestration of carbon and biodiversity conservation Van Panchayats in Uttarakhand selected in consultation with Uttarakhand Forest Department. The project is being developed in about 45,000 ha of Van Panchayat forest lands. The pilot project is financed by Uttarakhand Forest Department. Under the project, ICFRE intends to develop modalities for passing financial incentives to local communities that can make the REDD plus a success at local, sub-national and national level. For this purpose methodologies and modalities for a procedural framework to be worked out. The project will ensure people's participation and sharing of the benefits accruing from REDD plus incentives at local project level.

The objectives of the proposed project are:

services (PES) to the participating communities

- Estimate carbon status in different carbon pools in the selected Van Panchayat forests of Uttarakhand Estimate enhancement in forest carbon stocks as a result of conservation efforts in Van Panchayat forests Capacity building of participating communities for developing a transparent MRV system at small project level Develop a system of respecting and reporting of safeguards in accordance with the international agreements at UNFCCC Getting the project registered for carbon credits and develop a system of payment for ecosystem
- Forest Plus by USAID: USAID's new Forest-Plus program will accelerate India's transition to a lowcarbon economy by taking the United Nations Collaborative Program on REDD plus actions to scale began in 2012. This program will strengthen India's capacity to develop systems for forest carbon measurement and monitoring, as well as conduct greenhouse gas inventories, and support the application of science and technology for improved and more cost-efficient management and monitoring systems.

The Project will help to improve tools and capacity for land-use planning that reduces deforestation while also ensuring the rights and engagement of local and indigenous communities.

Under Forest Plus, pilot projects are being implemented in following parts of the country:

	Shimoga	(Karnataka))
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- ☐ Harda (Dist Hoshangabad Madhya Pradesh)
- ☐ East Sikkim (Sikkim)
- (iv) Chamba/Mandi (Himachal Pradesh)

The program will also support short-term collaborative research on carbon estimation methodologies in various Indian ecosystems

Forest-Plus Project work with the Ministry of Environment, Forest and Climate Change as the primary counterpart to support implementation of national policies and programs. The programme is a 28 million USD bilateral agreement and India's contribution is of 9 million USD to promote scientific and technical collaboration and exchange between India and U.S. under the sustainable landscapes pillar of the U.S. Government's Global Climate Change budget. The programme is divided into two components: Component one focuses on U.S.-India collaborative scientific research and exchanges to explore methods and approaches to implement REDD plus. Component two focuses on establishing government and stakeholder dialogue and communication process and engaging stakeholders constructively in REDD plus implementation. The activities under this agreement have been organized into two phases: Phase 1 includes conducting training sessions to bolster Indian expertise in completing carbon estimation, forest inventories and related analyses. Phase 2 included setting up pilot projects to demonstrate methodologies, tools and technologies in the Indian context.

- (iii) The Energy and Resources Institute (TERI), New Delhi is implementing small REDD plus pilot projects financed by the Norwegian Government in close association with Ministry of Environment, Forest and Climate Change and State Forest Departments. Pilot study for project design in 6 sites in different states of India has been initiated as per following details: (i) Temperate Forests (Mussoorie, Uttarakhand), (ii) Dry-Deciduous Mixed Forests (Renukoot, Uttar Pradesh), (iii) Moist —Deciduous Forests (Chhindwara, Madhya Pradesh), (iv) Moist deciduous-Mixed Forests (Angul, Odisha), (v) Mangrove Forests of Sundarbans (West Bengal) and (vi)Tropical Moist Deciduous Forests (Nagaland) (Source: Personal Ccommunication Dr. Suresh Chauhan of TERI).
- (iv) Umiam Sub-Watershed REDD-plus Project, Meghalaya: A pilot project in the East Khasi Hills in Meghalaya being run jointly by a California-based non-profit organization, Community Forestry International and the Mawphlang community (Meghalaya). They have been working together in the Umiam basin watershed region to develop a REDD plus Project in East Khasi Hills District of Meghalaya and finally registered in 2011 with Plan Vivo. The total project area is 17,052 ha. The net CO₂ additionality per year on account of avoided deforestation and degradation and afforestation in the project area works out as under:

2. Market mechanisms for forestry sector

An internal market mechanism aimed towards climate change mitigation is at a nascent stage in India. Unlike PAT (Perform Achieve and Trade) for incentivizing Energy Efficiency improvement and REC

(Renewable Energy Certificate) scheme to promote the use of renewable energy, India has not developed domestic carbon market mechanism under forestry sector. So far trading in the forestry sector is largely under the ambit of CDM and voluntary markets. India is one of the leading countries as far as CDM afforestation and reforestation projects are concerned. A list of CDM Afforestation/Reforestation projects registered from India is given in Table 5.1. Forestry projects registered in the voluntary market (Voluntary Carbon Standards) under sectoral scope AFOLU (Agriculture, Forestry and Other Land Use) are given in Table 5.2.

Carbon emissions in other sectors like energy can also be avoided to some extent by burning sustainably produced and harvested biomass instead of fossil fuels, e.g., using energy plantations to run a power plant, substituting industrial products that are currently fossil-fuel intensive in their manufacture with wood products (e.g., substituting cement by lumber). Use of biomass (of agriculture and forest origin) in substituting fossil fuel energy has led to many biomass CDM projects in India. More than 200 CDM projects have been registered from India using biomass (forest and other biomass) as raw material for energy production in a sustainable manner.

Table 5 1	CDM Afforestation / Reforestation projects from India		
S. No.	Name of CDM Project Activity	Registration Date	Estimated Emission Reduction (mtCO,eg/year)
1	Rehabilitation of Degraded Wastelands at Deramandi in Southern District of National Capital Territory of Delhi	30-Jan-13	12,138
2	through Reforestation (Small Scale) CDM-EB Ref 9549 Agro-forestry Interventions in Koraput district of Orissa	19-Nov-12	1,130
3	(Small Scale) CDM-EB Ref 8283 Reforestation of degraded land by MTPL in India CDM-EB Ref 5016	1-Aug-11	146,998
4	Bagepalli CDM Reforestation Programme CDM-EB Ref 4851	27-May-11	92,103
5	India: Himachal Pradesh Reforestation Project – Improving	4-Mar-11	41,400
6	Livelihoods and Watersheds CDM-EB Ref 4174 Improving Rural Livelihoods through Carbon Sequestration by Adopting Environment Friendly Technology based Agroforestry	28-Feb-11	4,896
7	Practices CDM-EB Ref 4531 The International Small Group and Tree Planting Program (TIST) Tamil Node India (Small Scale) CDM-EB Ref 2000	15-Jan-10	3,594
8	(TIST), Tamil Nadu, India (Small Scale) CDM-EB Ref 3000 Reforestation of Severely Degraded Landmass in Khammam District of Andhra Pradesh, India under ITC Social Forestry	5-Jun-09	57,792
9	Project CDM-EB Ref 2241 Small Scale Cooperative Afforestation CDM Pilot Project Activity on Private Lands Affected by Shifting Sand Dunes in	23-Mar-09	11,596
	Total CO ₂ abatement per annum		3,71,647

Source: www.unfccc.int

Table 5.2. Registered VCS projects under sectoral scope 14 (AFLOU) from India

S. No.	Project ID	Project Name	Estimated Emission Reductions (mt of CO ₂ eq per year)
1	1051	Community-based reforestation project on degraded lands in Uttar Pradesh, India by Indian Farm Forestry Development Co-operative Limited	5651
2	922	Plantation Project on wastelands by Sun Plant Agro Limited	108
3	689	Reforestation of degraded land in Chhattisgarh, India	5007
4	994	TIST Program in India, VCS 001	11047
	23,413		

Source: http://www.vcsprojectdatabase.org/



CLIMATE CHANGE ADAPTATION

Human and natural systems have a capacity to cope with adverse circumstances but, with continuing climate change, adaptation will be needed to maintain this capacity. According to IPCC fifth assessment report, adaptation is the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects (IPCC, 2014). Forests in India face significant pressures in the form of forest fires, livestock grazing, timber and fuelwood extraction, shifting cultivation, invasive species, pests, unsustainable extraction of forest products by forest dependent communities and diversion of forest lands to other uses. An estimated 275 million people living in rural areas of India depend directly on forests for at least part of their livelihoods (World Bank, 2006). Forest ecosystems provide a wide range of supporting, provisioning, regulating and cultural services (ecosystem services) and hence, adaptation of forests to climate change is of critical importance. Locally, forest management and silviculture are likely to influence carbon sequestration by trees, the reaction of forests to climate change and the forest services provided to local populations. The principles of sustainable management of forests can be applied to reduce the exposure and sensitivity of a forest and therefore its vulnerability, and/or to enhance its adaptive capacity. Sustainable management of forests, therefore, can play an important role in climate change adaptation. Some of the adaptation options in forestry sector are as follows (Murthy et al., 2011):

- (i) Effective implementation of existing policies/acts/guidelines: There is a need to improve and ensure effective implementation of existing policies/acts/guidelines such as the Forest (Conservation) Act of 1980; the Wildlife Protection Act, 1972 and 2002; and wildlife conservation programmes such as Project Tiger and Project Elephant, etc; Forest Rights Act, 2006.
- (ii) Expansion of protected areas: There is a need to increase area under protected areas and also to link protected areas, reserve forests and wildlife reserves. There is also a need to enhance area under Protected Areas in mountainous regions, ideally spanning an elevation gradient so as to facilitate species migration with increasing temperature. Expansion of protected areas again requires working with communities residing close to forest areas and providing alternatives for their livelihoods given the large dependence of communities on forests for subsistence and livelihood.
- Provision of natural corridors: There is a need to ensure the natural corridors, needed for migration of both plant and animal species under changed climate situation. This can be possible only by reducing fragmentation of forests and other ecosystems. This is however a difficult task given the large human population and fragmented nature of forests in India. New policies may be needed to involve local communities in such efforts, by creating livelihood opportunities.
- Afforestation and reforestation under climate change: India has a target of bringing one-third of its (iv) geographic area under forest cover and also launched the Green India Mission under which a thrust to afforestation has been given with a target to afforest additional 10 million ha of degraded forest lands. Given this large thrust for afforestation, there is a need to incorporate adaptation practices and adopt

- strategies such as mixed species forestry, planting of ecologically compatible and locally valued species coupled with soil restoration and anticipatory planting of species.
- (v) **Improved silvicultural practices:** The current silvicultural practices adopted in plantations, dominated by exotics and monocultures are enhancing the vulnerability of forests. Therefore, there is a need to develop and adopt silvicultural practices that would reduce vulnerability and enhance resilience. This requires research to identify practices that reduce vulnerability of plant species and forest types to changing climate parameters. Some of the potential silvicultural practices could be (i) promotion of natural regeneration in degraded forest lands; (ii) promotion of mixed species forestry, lesser known tree species on degraded non-forest lands (iii) anticipatory planting of species along the altitudinal and latitudinal gradient (iii) in-situ and ex-situ conservation of floral and faunal species (iv) adoption of short rotation species and (v) adoption of sustainable harvest practices for timber and non-timber products.
- (vi) Promoting community forestry: The Joint Forest Management model could be adopted for promoting community forestry to enhance the availability of fuelwood and fodder at local level in order to reduce pressure on forest resources.
- (vii) Decrease pressure on natural forests: Enhanced support to afforestation and reforestation programmes to meet the demand for timber and fuelwood, will reduce pressure on primary forests. Popularising improved cook stoves and alternative and fuel efficient sources of household energy will help in reducing pressure on natural resources.
- (viii) Forest fire management: Innovative and region specific fire management strategies need to be formulated as opposed to measures generally adopted for prevention of fire, not taking into consideration the risk of fire in a region and its impacts. Such strategies would enable management of different ecosystems for varied purposes such as grass production or tree species management.

Local knowledge and associated forest management practices have sustained local and indigenous communities throughout the world under changing environmental, social and economic conditions, long before the advent of formal forest science and 'scientific' forest management. Local forest-related knowledge is usually closely linked to traditional land-use practices, local decision-making processes and governance institutions, and beliefs about the relationships between community members and forest environments (Roberts et al., 2009). This together with the long understanding and association with forests, several aspects of contemporary forest management and policy can be viewed as adaptations to climate (Spittlehouse, 2005).

6.1 Sustainable land and ecosystem management in India

Sustainable land management (SLM) is defined as a knowledge-based combination of technologies, policies and practices that integrate land, water, biodiversity, and environmental concerns (including input and output externalities) to meet rising food and fibre demands while sustaining ecosystem services and livelihood) (UNCCD, 2012). To achieve Zero Net Land Degradation (ZNLD), the SLM options are defined as those land use and soil/vegetation management practices that create a positive carbon, water, and elemental balance in the used land, enhance net primary productivity, mitigate climate change by absorbing atmospheric CO₂ and sequestering it in biomass and soil, and can be adapted to environmental conditions. The overall goal is to adopt SLM practices that protect topsoil, conserve and enhance plant available water in the root zone, and strengthen nutrient cycling while improving soil fertility. With reference to cropland, SLM practices that will assist in achieving ZNLD include residue retention and mulching, growing cover crops, using manure and compost, and adapting complex rotations to enhance the soil organic carbon pool and improve soil quality.

As a signatory to the United Nations Framework Convention on Climate Change, United Nations Convention to Combat Desertification and the Convention on Biological Diversity, India is committed to meet the objectives under these agreements to address the impacts of climate change, biodiversity loss and desertification and integrate the principles of sustainable development into country programmes and reverse the loss of environmental resources. In India, Sustainable Land and Ecosystem Management (SLEM) a joint initiative under the Country Partnership Programme of the Government of India and GEF was initiated in 2006. The programme was led by the Ministry of Environment, Forest and Climate Change in coordination with Ministry of Rural Development and Ministry of Agriculture at the national level, and collaborated closely with state government authorities and other stakeholder groups at the local level. The overall objective of SLEM was to promote sustainable use of biodiversity as well as maintain capacity of ecosystems to deliver goods and services and support livelihoods while addressing challenges to biodiversity from climate change. To achieve this, a number of organizations representing different capacities related to the issues at hand participated in the programme. These included government organizations at union and state levels, non-governmental and civil society organizations. The donor community as stakeholders in the SLEM program was also perceived as an important partner. The programme had a cross-cutting and synergetic approach to achieve multiple global environmental benefits in the context of sustaining rural livelihoods from managing natural resources in a sustainable way.

The Ministry of Environment, Forest and Climate Change designated ICFRE as Technical Facilitation Organisation for the Medium Scale Project titled "Policy and Institutional Reform for Mainstreaming and Up-scaling Sustainable Land and Ecosystem Management in India". The project started in August 2009 and completed in June 2014. The main aim of this project is to "enhance the institutional and policy framework for harmonization, coordination and monitoring of interventions in agricultural and natural resource management strategies that promote sustainable land management and enhance agricultural productivity while minimizing environmental impacts". The broad objectives of SLEM-MSP are:

- To ensure that SLEM-CPP improves sustainable land ecosystem management at both national and 1. state levels, and in activities by the civil society.
- 2. Provide policy, strategic and operational guidance on the direction of sustainable land and ecosystem management within SLEM-CPP and with policy-makers in India.
- 3. Ensure coordination and networking of all organizations with responsibilities related to land and ecosystem management in India.
- 4. Gather and disseminate information and experiences on sustainable land and ecosystem management to a wide audience.

SLEM, a multi-stakeholder programme involved a consortium of partners: the World Bank, United Nations Development Programme (UNDP) and the Food and Agriculture Organization (FAO). SLEM-CPP drew the collective strength from seven projects endorsed by the Global Environment Facility (GEF) Council under each of its three focal areas - Land Degradation, Biodiversity Conservation and Climate Change (Table 6.1). The project sites covered diverse ecological zones including arid, coastal and mountainous ecosystems and addressed diverse aspects of land and ecosystem management including coastal agriculture, shifting cultivation, watershed management, and groundwater management. The States where SLEM-CPP operated include, Uttarakhand, Nagaland, Andhra Pradesh, Rajasthan, Himachal Pradesh, Madhya Pradesh, Maharashtra, West Bengal, Odisha, and the Union Territory of Andaman and Nicobar Islands. Some of the adaptation oriented activities of the SLEM-CPP are listed in Table 6.2.

Table 6.1. List of projects under sustainable land and ecosystem management country partnership programme

GEF Implementing Agency	Project Name	Project area	Implementing Agency
The World Bank	Policy and Institutional Reform for Mainstreaming and Upscaling Sustainable Land and Ecosystem Management in India	All the states	ICFRE, Dehradun
	Sustainable Land and Biodiversity Conservation and Management for Improved Livelihoods in Uttarakhand Decentralized Watershed Management	Uttarakhand	Uttarakhand Watershed Management Directorate,
	Sustainable Rural Livelihood Security through Innovations in Land and Ecosystem Management	Coastal region of Sundarbans, Odisha and Maharashtra, Andaman & Nicobar Islands, HP, Rajasthan, AP, MP, Haryana	Indian Council of Agriculture Research, Ministry of Agriculture New Delhi
UNDP	Integrated Land and Ecosystem Management to Combat Land Degradation and Deforestation in MP	Madhya Pradesh	MP State Forest Department
	5. Sustainable Land Management in Shifting Cultivation Areas of Nagaland for Ecological and Livelihood Security	Nagaland	Nagaland State Department of Soil and Water Conservation, & Village Council and Village Development Board, Kohima
	6. Sustainable Participatory Management of Natural Resources to Control Land Degradation in the Thar Desert Ecosystem.	Rajasthan- Thar Desert	Minstry of Rural Development, Government of Rajasthan and the Jal Bhagirathi Foundation
FAO	7. Reversing Environmental Degradation and Rural Poverty through Adaptaion to Climate Change in Drought Stricken Areas in Southern India	Andhra Pradesh	Bharati Integrated Rural Development Society

Source: TFO-SLEM, Policy and Institutional Reform for Mainstreaming and Upscaling Sustainable Land and Ecosystem Management in India. Annual Progress Report (April, 2011 to March, 2012) Directorate of Extension, ICFRE, Dehradun

Table 6.2. Some climate change adaptation activities under SLEM-CPP

S.No.	Activities	Target Areas	Adaptation measures
1.	Chauka system for management of common property resources in dry regions of Rajasthan	Sustainable livelihood and adaptation to climate change	 i) Pasture improvement and run of harvesting ii) Improvement in ground and other water resources iii) Improvement of livestock iv) Improvement in crop and fodder productivity v) Improved biodiversity conservation
2.	Agro-biodiversity innovations in Odisha	Sustainable land and ecosystem management	 i) Development of new crop calendar for selecting salt, drought & flood tolerant varieties of rice, late sowing of rice to combat natural calamity like flood ii) Ancillary enterprising activities started like mushrooms, pisciculture, apiary and backyard poultry
3.	Aonla based agro-forestry in semi arid dry regions of Rajasthan	Ecosystem and management practice	 i) Adoption of soil and water conservation, field bunding and leveling ii) Improved ground water status ii) The conventional Bajra-Mustard cropping system is being replaced by Aonla based agroforestry with bajra, gaur, mustard and wheat as inter crops
4.	Managing ground water in southern India	Adaptation to climate change	i) Reduction in ground water usageii) Artificially ground water rechargeiii) Ground water management
5.	Land shaping in Sunderbans	Climate change adaptation and sustainable livelihoods	 i) Farmer's income increased three times after the intervention of land shaping techniques ii) This empowered women folk in the region who now take interest in other development programmes
6.	Wadi: a tree based farming system in Gujarat.	Sustainable land and ecosystem management	 i) The Wadi system consists of horticultural crops with forestry species on the periphery of the land holding and annual crops in the interspaces of the food crops ii) Multipurpose trees grown along boundaries serve as a source of family's fuel, wood, fodder and additional income iii) Mature fruit trees become a source of livelihood for the poor families year after year
7.	Participatory model for water harvesting and development of community pastures in	Water Management	A corpus of fund called 'Jal Kosh' is raised from the income of selling the harvested water or grass/grass seed from the pastures. The funds could be utilized as share of the participants for

	Thar desert		welfare activities of the society.
8.	Rehabilitation of degraded bamboo forests in Madhya Pradesh	Sustainable land and ecosystem management	To treat degraded bamboo forest, the state forest department allotted 20 ha area for four years (5 ha/year) to the poor tribal families residing nearby these forest. Monthly and annually remunerations were provided to each family
9.	Sustainable land and ecosystem management in shifting cultivation areas of Nagaland	•	i) Integrated farming model was adopted which improved soil fertility and water retention ii) Farmers were able to cultivate same plot of land for three or more years

Box 6. GEF - SLEM of Uttarakhand

Reducing pressure and Dependence on the Natural Resource Base through Fostering Markets for NTFPs

Heavy pressure on forests for meeting fuelwood demands leads to degradation of forestland resulting in

loss of soil and moisture, drying up of natural water sources, biodiversity depletion and adverse impact on agricultural yields. To reduce the dependency of households on forests for fuelwood, three specific activities have been carried out, namely pine briquette making/distribution of briquette stoves, installation of bio-gas and distribution of solar cookers. The technology to convert chir pine (*Pinus roxburghii*) needles to briquettes for household energy will encourage people in the project area to go for pine briquetting as an alternate source of clean fuel which can also serve as an income generation activity for village women. This is a technique for fuel switch from traditional wood-based fuel to a non-wood based on which will go a long way towards reduction of fuelwood collection from adjoining forest areas. In the hilly areas of Uttarakhand, exploitation of forests for meeting day to day fuelwood needs of rural people has put tremendous pressure on the forests which have degraded extensively in the vicinity of habitation. The availability of alternative cooking energy through biogas thus reduces the pressure on forests for fuelwood, about 4.6% of household surveyed have reported a reduction in the number of rounds for fuelwood collection and about 29.3% of households have reported a reduction in the number of days (in a year) that are spent for fuelwood collection. Approximately 2,400kg/yr of fuelwood was



GAPS AND CONSTRAINTS IN ADAPTATION AND MITIGATION ASPECTS OF FORESTS

India is in a reasonably comfortable position vis-à-vis many of the other developing countries, as far as the capacity to implement climate change forestry programmes is concerned. Still a lot needs to be done on the capacity building front. Various initiatives taken by the Ministry of Environment Forest and Climate Change, Government of India has helped in capacity building of State Forest Departments, NGOs, Civil Society and other stakeholders to create an enabling environment for CDM Afforestation/ Reforestation Projects in India; with the result that today, India is a leading country in CDM Afforestation/Reforestation Projects in the world.

7.1 Local capabilities

The institutions available at local level to deal with the forests include 'Gram Sabhas', Joint Forest Management Committees, Community Forest Management groups (a large number in Orissa), 'Van Panchayats' (Uttarakhand), village councils (North-east), etc. Self help groups/common interest groups have also been set up at village level to promote forest based livelihood activities. The spread of Joint Forest Management has helped in regenerating forests and meeting local needs.

7.2 Evaluation of current capacity building needs

Forestry sector in India is at the threshold of unprecedented opportunities. Forests are increasingly recognized as a key ingredient in resolving global issues such as poverty, climate change, biodiversity loss and natural resource supply. These opportunities, if effectively realized, could both enhance the livelihoods of forest-dependent people and improve the state of the forests by providing steady funds and ultimately allowing forest-dependent people to sustainably manage the forests around them and rise out of poverty. Full and effective participation of indigenous people and local communities in developing, implementing and monitoring climate initiatives in forests require investments in capacity building and inclusive decision-making process. Financial resources for such investments needed for successful implementation of the same, as currently no such mechanisms are specifically available.

On the technical front, considerable capabilities have been developed in India in forest resource assessment; however; a lot still needs to be done. The resolution of data used in satellite images is not very high. More capacities need to be built in this direction. Also, the resource assessment at the State and local level is not upto the mark. Capacity building exercise needs to be carried out upto community level. Capacity building in climate change of following stakeholders is required:

(i) Strengthening local community institutions: Strengthening decentralized governance through 'Gram Sabhas' (Village level Institutions) and other thematic committees/ local institutions have significant bearing on forest conservation and its sustainable use. Comprehensive approach and programmes should therefore strengthen Gram Sabhas as overarching institutions. Larger landscape level governance/management needs to emerge over time, engaging a diversity of institutions depending on the local context and learning from the successes and failures of initiatives at

- landscape/sub landscape level. Uniform guidelines across the states are needed to develop climate and forestry actions at national level.
- (ii) Capacity building of local institutions: Building capacity of local institutions is needed under climate mechanisms to help them effectively protect, regenerate and manage forests. Creating community stake in regeneration of forests/restoration of ecosystems requires that communities have sufficient stake in terms of enhanced biomass, NTFPs and environmental services from such areas. Community driven innovative/adaptive silviculture is of critical importance to successfully implement mitigation/adaptation strategies in conservation of ecosystems and enhancement of carbon stocks. There should be greater space for local level planning and management for forest/ecosystem restoration with special reference to carbon sequestration.
- (iii) Building a cadre of rural youth: Given the fast changing rural scenario with increase in the number of educated unemployed/underemployed youth, climate programmes should support development of youth cadres to lead the charge at the local level. Support of research institutions, universities/colleges from local area, forest department and NGOs would help develop this cadre as self employed change agents. The cadre of community youths will help streamline the climate activities at the local level with active support of SFD and other agencies. This will also augment capacity of forest department to facilitate Green India Mission activities with existing regular staff.
- (iv) Strengthening Forest Department and other partner agencies: In order to ensure an integrated approach under climate change at village/cluster/sub-landscape/ sub- watershed level, the forest department will need new capacities. Capacity building activities should support upgradation of the Forest Range Offices into a Forest and Wildlife Resource Centre (with library, documentation, map room, GIS and MIS cell facilities).

It would also be appropriate to say that at national level; a reference guide needs be prepared that provides information material on climate change programmes and its implications for the key stakeholders. It should help in developing understanding of climate change programmes like GIM, CDM and REDD-plus and how they relate to the recognition and exercise of the collective rights and responsibilities of the stakeholders. Apart from this, there should be a 'Manual for the Trainers' as a companion resource to the stakeholders' guide. It should be written for trainers who intend to conduct training workshops for key stakeholders like forest department personnel, indigenous leaders, community members and others (Singh and Rawat, 2013).

7.3 Gaps and Constraints

There are numerous gaps and constraints, which hamper undertaking of research activities in climate change with respect to forests (Singh *et al.*, 2014). Some of these are summarized below:

(I) Knowledge gaps: Though climate change is global issue, still there are some gaps and constraints visible in knowledge of adaptation and mitigation from point of view of forestry. Key knowledge gaps include linkages between impacts of climate change and adaptation and mitigation options. More research is required to better understand climate change challenges and cost-effective solutions at the local levels and to fill knowledge gaps. Despite the emergence of more and more regional and country-specific studies on climate change in India in recent years, knowledge gaps remain. Hence, there is an urgent need for undertaking more research at regional level to better understand climate change and its impact, risks and vulnerability, adaptation needs, and mitigation potential at local levels.

- (ii) Financial gaps: Government of India has initiated its National Action Plan on Climate Change with equal thrust on climate change adaptation and mitigation strategies (MoEFCC, 2014). Financial estimates of these actions have not been fully converted into budgetary allocation. This makes implementation difficult in the absence of resources and competing priorities. There is need to translate policy statements into strategies and strategies into budgetary allocations. It is important to make simple and easy approachable rules and regulation to funding the project work related to adaptation and mitigation activity.
- Research gaps: There is a considerable gap in our knowledge of the natural resources of India. A study undertaken by International Centre for Integrated Mountain Development in the Eastern Himalayas and their vulnerability to climate change indicated that there is no systematic monitoring, documentation, or research to check the status of biodiversity in the region (ICIMOD, 2009). Despite various projections and observed changes, the region also lacks adequate scientific evidence to understand the impact of climate change on different aspects of human wellbeing. Across the entire region, most of the limited research that is available focuses on the adverse impacts of climate change and overlooks the adaptation mechanisms that local people have developed themselves, and the potential new opportunities. There also appears to be a lack of human and institutional set ups and policy imperatives to tackle climate change issues. The shortcomings are there, mainly as a result of lack of reliability in observed trends and model projections resulting from the lack of consistent country wise data in relation to climate change.

A strategic approach is needed for detailed research on different ecosystem services and functions to estimate the potential impacts of climate change. Such research could develop adaptation mechanisms and/or highlight mechanisms that have already been implemented by local people in response to the changing environment. Detailed indicative research is also essential to define mitigation strategies at the policy level that need prioritizing at the government/international level.

- **Technological and capacity building gaps:** A well equipped trained human resource to man technical devices concerned to research activity is lacking at many places. The status of forestry statistics has become a cause of concern because there is a vast gap in the current technology applications and their adaptation to the day-today working of forest research. The existing capacity to collect data at regional level is weak. Before implementing technological advances in statistical data reporting work, it is necessary to build adequate capacity for collection of data from primary sources. The capacitybuilding programmes and skill development programmes should have a sustainable structure aiming at timely upgrading with the technology.
- **Institutional constraints**: There are some constraints to undertake research activity in the field of adaptation and mitigation to climate change in forestry sector because there is no such organized and effective institutional framework in India to operate proper work in this field.
- Gaps and constraints at policy level: India was among the first few countries in the world to provide (vi) for the protection and improvement of the environment in the national constitution, and it has taken several steps in designing policies and legislation to overcome environmental problems. India has launched the National Action Plan on Climate Change in 2008 which is still in its initial phase (MoEFCC, 2014), so a lot of works are needed to be done to spell out the contours of the 'eight missions'. Cumulatively, over a period of years, the missions could help in gradual removal of bottlenecks at the policy level, as well as provide a strategic shift to enhance adaptation and mitigation activities. There is also a need to develop sector-specific climate policies, measures and regulations that could help in adaptation and mitigation activities.

(vii) Gaps and constraints in data collection and impact assessment capacity: Climate change has wide implications in the diverse Indian forest sector. Therefore there is a need to develop mitigation strategies and projects, maintain a periodic inventory of the greenhouse gases emissions and removal, promote sustainable management of forests, and sustainable production of timber, fuelwood and biomass feedstock for energy for reducing the vulnerability of forest ecosystems. Data limitations related to various pertinent issues such as forest vegetation characteristics, plant functional types, plant physiology aspects, soil and water and socio-economic implications etc. need to be overcome by initiating studies to develop databases (Chaturvedi *et al.*, 2008). Absence of forestry functional related data limits the future projection of changes in India's forests. This limits the strategies for adaptation and mitigation too. Therefore, core research on this aspect is a major constraint for forestry under climate change regime.

Improving data collection and sharing results at national, regional and international levels will improve the quality of work regarding adaptation and mitigation. It can also increase the detail of climate impact assessments to a scale that is meaningful for optimizing adaptation and mitigation measures, and operating nearly real-time, early warning and hotspots warning systems for forestry in India. This refers particularly to the 10 to 15 years time horizon over which the reliability of impact projections is probably acceptable and the planning of responses is probably realistic. Better data will improve access to international funding mechanisms. National extension and forestry research services have an increased role to play in data collection, analysis and use for decision-making and decentralized service to nation well being. There is also a need to include social science research to boost understanding on how people adopt and implement adaptation and mitigation options.

There is continued need for a better meaningful and result oriented productive research work in climate change adaptation and mitigation in India. While, the country has potential to overcome to barriers related to undertake research activity but commitment to implementation is challenged by inadequate human and financial capacities.

Training programmes: Ministry of Environment, Forest and Climate Change through its research and training organizations is regularly providing inputs on the subject of climate change and forestry to the officers of Indian Forest Service, trainees of Central Academy for State Forest Service and scientists and technologists working in Government sector. REDD plus is another important area, which needs enormous capacity building programme. India can help in the capacity building programmes of other non Annex countries under the climate change collaborations. A suitable multilateral financial mechanism needs to be developed to operationalize such capacity building programmes for countries intending to participate in such activities.



RESEARCH THEMES AND PROPOSALS ON ADAPTATION AND MITIGATION ASPECTS OF FORESTS

Research in climate change is multi-disciplinary. There is a need for an integrated approach to study the problem cutting across disciplines of physical, social, biological, and engineering sciences. Forestry can contribute immensely towards climate change mitigation. In India, a limited number of studies have been undertaken to address the climate change concerns vis-à-vis forests and forest products. There is a need for a quantum increase in such studies as this is the major sector that can contribute to climate change mitigation.

Climate change requires a global framework for international cooperation. Adaptation action is a vital part of this framework. Actions to enable adaptation to climate change provide opportunities to promote sustainable development. In the present context, resources are required to promote these actions. Networking of institutions working on forestry and allied sectors must be effective. Collaboration and cooperation between all such institutions can directly engage multiple stakeholders dealing with climate change along with coordinated planning and actions. This could be facilitated by a nodal agency at the central level with the participation of relevant stakeholders involved. Raising awareness about forests and climate change among the key sectors and mass media including current events such as economic, weather, and health crisis can also help promote adaptation measures with co-benefits.

Taking stock of and promoting good practices adopted by communities in the integration of climate change related issues would help to promote adaptation strategies with multiple benefits. In the context of future research on forests and climate change issues, additional financial resources need to be sufficient, predictable, and sustainable in order to facilitate adaptation to the adverse impacts of climate change on communities as well as funding envisioned through the international cooperation under UNFCCC and other multilateral and bilateral instruments.

8.1 Identification of specific research themes related to adaptation and mitigation aspects of forests

The present state of knowledge of the relationship between climate and plant performance is grossly inadequate for the purpose of modelling future climate change impacts. Research in the following areas is thus key for coming up with robust adaptation strategies:

- i) Research on the ecology of plant and animal species and communities in relation to climate variability and change: Keeping in view the sensitivity of plant and animal species to climate variability and change, ecological studies of plant and animal species, plant-animal interactions and community in relation to climate variability and change is required to be carried out.
- ii) Dynamic vegetation modelling of climate change impacts on forest ecosystems, biodiversity and adaptation: The few studies so far conducted in India are largely based on equilibrium models, which assume that one forest type is replaced by another forest type under changing climate scenario. The

varying climate tolerances of different plant species and the transient phase response of plant species subjected to climate change have not been analyzed. There is a need to adapt the existing dynamic vegetation models for application to the diverse tropical forest-types in order to analyze implications of climate change at species level. The ultimate goal is to develop adaptation strategies and practices to reduce vulnerability of forests to climate change. The modelling effort should incorporate adaptation.

- iii) Impact of climate change on mitigation potential, carbon sinks and adaptation: Under the Green India Mission, India is developing a large afforestation programme and it is important to understand the likely impacts of climate change to ensure sustainable management of forests and flow of timber, industrial wood and non-timber products and conservation of biodiversity.
- Mitigation potential assessment: There is also a need to develop a database on biomass growth rates iv) and soil carbon accumulation rates in forests and plantation systems in different agro-ecological zones of India. This data is required for a more realistic assessment of the mitigation potential of forest sector in India.

v)	Indicative research themes on adaptation and mitigation aspects of f	orests:
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Evaluation of current vegetation composition of different forest types and vegetation dynamics in the ecotone regions of the important forest types
Identification of species having potential of becoming pest/invasive under climate change scenario
Updating forest inventory data on regular basis
Inventorization of invasive and alien species (species migration due to climate change)
Estimation of wood specific gravity (as indicator of capacity and efficiency of CO_2 sinks) of different forest types, forest stands or plantations
Screening of fast growing species/varieties/clones for higher biomass production
Determine the effect of climate variability and change on patterns of tree physiology, growth and wood formation
$Identify the \ relative \ sensitivity \ of \ different \ plant \ species \ to \ climate \ variability \ and \ change$
Impact of climate change on species composition and diversity in selected forest types
Development of appropriate silviculture practices and determination of optimum stocking level
Selection of tree species best adapted to existing sites- matching species and site
Protection from fire (Fire Management), pest and diseases: Modern Forest Fire Management and Integrated Pest Management
Establishment of <i>in situ</i> and <i>ex situ</i> reserves of key forest species to ensure availability of gene pool of sufficient variability for current and future tree improvement programme with the objective of developing varieties capable of adapting to climate change
Insect disease monitoring programme with the aim of detecting increase in occurrence and intensity of such events and activity of new pests
Research to determine effect of long term climate change on biology of disease pest-host interaction of traditional pest species
Study of possible influence of climate change on productivity of plantations

Sensitivity of mangroves to changing climate
Monitoring of temporal changes in soil carbon, and nitrogen in agroforestry systems in different agro-climate zones
Dynamics of insect populations as indicators of forest and environmental health in relation to climatic changes
Populationdynamicsofspecificinsectgroupsinrelationtovaryingclimaticconditions
Tree canopy- insect interaction in relation to climatic change
Regeneration of forest species in degraded forest areas and estimation of biomass
Studies to enhance soil carbon through vegetative and chemical manipulations
Improved utilization of wood and wood products through enhanced durability under terrestrial and marine conditions – an approach to more and longer carbon locking
Control measures to defer weathering of wood polymer composites with a view to postponing ${\rm CO_2}$ emissions
Measures to check biodegradation of wood polymer composites
Effect of wood coatings on durability and strength properties of wood
Role of forest/plantations in generating environmental services, and physical and financial valuation of these services, namely containment of SO _x , NO _x in atmosphere, amelioration of microclimate, noise abatement, soil and wood carbon, and water and soil conservation.

8.2 Examples of short research proposals related to adaptation and mitigation aspects of forests

8.2.1 Evaluation of forest dynamics and climate change through permanent plots

Climate change has the potential to alter terrestrial carbon storage, temperature, precipitation, soil carbon and decomposition rates, etc. Long-term impacts of climate changes and their variation could significantly impact forest developmental processes. A change in climate would be expected to shift plant distribution as species expand in newly favorable areas and decline in increasingly hostile locations. The establishment of permanent plots may be one of the viable options to understand the structure and functioning of forest ecosystems in perpetuity. These plots act as miniature laboratories for observing and understanding the interaction of plant species and communities with climatic variables.

Tentative Objectives:

To determine the changes in biogeochemical cycling of forest ecosystems
Effect of climate change on ecosystem composition and structure
To study the impact of climate on pattern functional aspects
Impact of climate change on soil physico-chemical properties and soil including microbiological properties
To study phenology of selected tree species in relation to climate change

This study can help in providing information on dynamics of forest biological diversity, composition and distribution over a long time period affected by climate.

Sub-Component: Estimation of regeneration potentials of the dominant forest species

Poor regeneration could be the first visible symptoms of the impact of climate change on forest vegetation. Evaluation techniques for regeneration have tended to correlate seedling frequency and distribution of advanced regeneration to a desired future stocking level. Seedling size and vigour could be another parameter to predict regeneration. Advanced regeneration in a forest stand can be evaluated by incorporating seedling and sapling size and vigour indices in permanent plots with the following objectives.

Tentative Objective

- ☐ Estimation of regeneration status for different species in different sub-group types
- ☐ Temporal performance of regeneration for different species in different sub-group types and their linkages with climatic parameters

Sub-Component: Investigation of plant invasion in natural forest stands

The movement of organisms beyond their natural range can have consequences that are ecologically or economically significant. Spatial and temporal course of range expansion by various organisms is now being tracked by various climate change researchers. A major goal of investigation will be to determine if invasion can be predicted. However the relationship between plant invasion and disturbances is still uncertain. Invasion can be attributed to site disturbances or it may be because of climate change.

Tentative Objective:

- ☐ Investigation of composition of natural stand on temporal basis
- Evaluation of linkages with climatic and anthropogenic disturbances

Sub-Component: Models for predicting tree and stand growth and yield

Growth and yield of forest are likely be affected by climate change. Tree growth is influenced by genetic capabilities of a species, interacting with climate, soil, topographic factors tempered by competition with other trees, lesser vegetation and animals. This affects the carbon sequestration potential of natural forests. Therefore tree measurements will be helpful for temporal evaluation of carbon capturing by the forest.

Tentative Objectives:

- ☐ Development of growth and stand models
- Evaluation of carbon potential

8.2.2 Evaluating and monitoring theimpact of climate change on plant diversity in mountain forests

Climate variability and change has broad effects on physical and ecological attributes of ecosystem compositions, structure, and function. The direct effect of increasing carbon dioxide concentration on plants includes changes in forest health, plant ecology, growth attributes, biodiversity, etc. Elevated CO₂ and increasing temperature affects plant population structure and dynamics, micro-evolutionary processes and plant community structure. These changes may contribute to declining biodiversity. Thus it is important to assess the likely impacts of projected climate change on forests and develop and implement adaptation strategies for both biodiversity conservation and the livelihoods of forest dependent people.

This study will help to understand the relationship between the forest ecosystem and stressors in terms of bio-indicators. The study will provide the analysis on impact of climate variables on structure and composition, phenological pattern and regeneration status of plant species in permanent preservation plot which will be helpful in future biodiversity conservation planning.

Tentative Objectives:

- ☐ To study the phenological and regeneration status
- ☐ To evaluate changes in plant diversity and study linkages with climate change
- Periodical monitoring of forest composition for establishing cause effect relationship between threats to biodiversity due to climatic factors
- ☐ To identify sensitive floral species for bio-indicators of climatic change.

8.2.3 Valuation of forest ecosystem goods and services

Forests have emerged as a prime issue in international political, policy, socio-economic, cultural, environmental and trade agendas. Forests provide a range of tangible and non-tangible benefits, both marketable and non-marketable, to society. Lack of knowledge about multiple functions of forests has led to under-valuation of goods and services they provide. Valuation of these goods and services provided by forests is essential to assign appropriate monetary value to the forests and plantations.

Tentative Objectives:

- ☐ To carry out assessment of environmental goods and services imparted by major forest types in the country
- ☐ To determine the location specific utility of various environmental goods and services
- ☐ To create database on goods and services of major forest types in the country

8.2.4 Inventory of forest soils of India

The productivity of forests in India is very low i.e. one third of the world's average. It is therefore imperative to know the causes of low productivity of Indian forests. As nature and state of soils may be one of the reasons for the lower productivity, it is therefore, imperative to know the state of forest soils. For proper land use in forestry sector, inventory of forest soils on the basis of ground truth information is essential because the soil map prepared for a forest area is extrapolated on the basis of few sampling points. Proper management of forest soil resource may be made if their inventory is made on the basis of ground reality.

Tentative Objectives

- ☐ To collect ground truth information of forest soil of India
- ☐ To prepare inventory of forest soils of India especially on soil organic matter

8.2.5 Impact of climate change on productivity and quality of medicinal plants

Medicinal plants as a group comprise approximately 8,000 species and account for about 50% of all the higher flowing plant species of India. About 90% of medicinal plants used by the industries are collected from the wild (Planning Commission, 2000). In recent years the growing demand for herbal products has led to a quantum jump in volume of plant material traded within and outside the country. The IUCN report for the year 2000, revealed that India ranked fifth in the case of threatened plant species and birds. Various reasons have been theorized for extinction of the species, climate change being one. These also influence the quality of active ingredients, therefore the demand and supply scenario may change. Keeping above into consideration, this vulnerability is being adjudged with following objectives:

Tentative Objectives

- ☐ To analyse climate change impact on productivity of region specific medicinal plants
- ☐ Chemo-profiling of selected medicinal plants for their major active ingredients
- ☐ To find out variation in major active ingredients in relation to climate change

8.2.6 Pathogens, diseases, mycorrhizae and climate change

Component 1: Climate Change: Influence on forest diseases and mycorrhizal fungi: The linkages of climate change with diseases of forest plants are not well established in Indian scenarios. However, it is predicted that climate change will shift pests to new areas. Some studies, though not directly addressing these may provide a link to these impacts. Sal mortality in central India in 1970s and 1980s had been correlated with successive drought years. Mortality of Acacia nilotica trees in Punjab has been correlated with extended period of fog and frost during winters. Mortality of deodar and pines in Himachal Pradesh has been correlated with climate change. It can be visualized that climate change will affect host-pathogen interactions by:

- ☐ Increasing insect pests and pathogen development rates, transmission and number of generations/life cycles per year
- ☐ Relaxing over-wintering (perennation) restrictions on pathogen life cycles
- ☐ Modifying host susceptibility to infections

Tentative Objective: To assess influence of climate change on fungal pathogens and symbionts of forest species.

Component 2: Forest fungi: Carbon losses and sequestration: Microbes, particularly fungi in forest areas, are critical players in the carbon cycle and sequestration. Nearly half of the soil biomass is consists of microbes including bacteria, actinomycetes, fungi, protozoa and nematodes. Fungi which utilize lignin and cellulose from woody substrates are crucial in maintaining the carbon balance on the forest floor. They store carbon in their mycelium and fruiting bodies both above and below ground and convert complex forms into easily assimilable ones.

The study of dynamics of the forest fungi and quantification of carbon losses and storage by them will provide useful information to utilize carbon resources judiciously. Some of the fungi are indicators of changes in the ecosystem such as fruiting of gasteromycetous fungi on forest floor which have experienced forest fire, Cyclomyces spp. occurring on newly exposed soils such as after landslides, etc. Systematic studies of forest fungi in relation to changes in climatic conditions will be important tools for determining their contribution as carbon sinks.

Tentative Objective: Estimation of fungal diversity involved in carbon cycle and sequestration and signs of climate change.

Component 3: Bamboo mycorrhizae: Bamboos are one of the fastest growing canopies for re-greening wastelands of India. Moreover, bamboos are highly mycotrophic (dependent on mycorrhiza) due to their fast rate of growth and shallow root system.

Tentative Objectives: To investigate role of mycorrhizal fungi in production of soil stable aggregates and soil carbon sequestration with bamboos.

8.2.7 Measuring above ground and below ground carbon pools and fluxes under different forest ecosystems in India

Trees capture CO, from the atmosphere. A large portion of this carbon is sequestered in their long lived structure, the trunk and largest branches. The turnaround time for this carbon is low, on the order of many decades to centuries. Traditional forestry has developed ways and means to quantify commercially valuable increment in stem volumes or above ground stem mass. However, more than half of the carbon that is captured as net primary productivity annually may get allotted to more ephemeral structures such as foliage, twigs and branches, bark and non-structural roots. These components are shed from trees at either regular or irregular intervals.

Soil carbon stocks are one of the largest carbon pools in the forest ecosystems. Coarse root biomass can also be a large pool, with value of mature stands typically ranging from 20-30% of the carbon content in above ground woody biomass. Accurate estimates of these pools are necessary to quantify current carbon storage and to understand the potential for factors such as elevated CO₂, climate change chronic N deposition, land use change and catastrophic disturbance to alter ecosystem Carbon storage and net Carbon exchanges.

The proposed research project deals with measurement of flow of above ground solid material to forest floor as litter fall and branch fall as well as decomposition from these plant parts and their release of carbon back to atmosphere and nutrients in ecosystem.

Tentative Objectives

The study for measuring above ground and below ground carbon pools and fluxes under different forest ecosystems and/or forest types can be undertaken with following objectives:

- Measurement of flow of above ground solid material to forest floor as litter fall and branch fall
- ☐ To estimate decomposition from these plant parts and their release of carbon back to atmosphere and nutrients in ecosystem
- ☐ To estimate dead wood decomposition rates to better understand short and long term contribution of dead wood to the carbon balance of forest
- ☐ Estimation of soil carbon pools in the forest ecosystems
- ☐ Estimation of coarse root biomass and their contribution in carbon cycle

8.2.8 Ecological assessment of indigenous tree species for carbon sequestration under different agro-ecological regions in India

The terrestrial biosphere is estimated to sequester large amounts of carbon (approximately 2 billion metric tonnes of carbon per year) (IPCC, 2001). Research problem under this program area seeks to increase this rate while properly considering all the ecological, social, and economic implications. There are two fundamental approaches to enhancing carbon sequestration in terrestrial ecosystems: (i) protection of ecosystems that store carbon so that sequestration can be maintained or increased; and (ii) enhancement of the ability of ecosystems to increase carbon sequestration beyond current conditions. The forest ecosystems offer significant opportunity for carbon sequestration, the focus includes below-ground carbon and long-term management and utilization of standing stocks, understory, ground cover, and litter.

Tentative Objectives:

- Screening of indigenous tree species for higher biomass production from different agro-ecolgical regions of India
- ☐ Estimation of biomass production, organic productivity and carbon sequestration potential of selected promising indigenous species from different agro ecological regions of India
- Developing biomass expansion factors, factors for root shoot ratio of the selected species for prediction of biomass at ecosystem level

8.2.9 Socio-economic adaptation to climate change among forest dependent community in India

Climate change will have wide-ranging effects on the environment, and related sectors, such as water resources, agriculture and food security, human health, terrestrial ecosystems and biodiversity and coastal zones. This ultimately impacts the deliverables of ecosystem services. These changes in flow will seriously

impact the poor, who are primarily dependent on these ecosystems or derive significant amount of products for their survival.

Developing countries are the most vulnerable to climate change impacts due to their poor resources base to adapt: socially, technologically and financially. Climate change is anticipated to have far reaching effects on the sustainable development of developing countries including their ability to attain the United Nations Millennium Development Goals by 2015.

The impacts of climate change are widespread. Because of these changes, the associated vulnerability should be assessed well in advance and needs to be reduced by improving the capability and capacity to adapt to predicted changes and impacts. There are many options and opportunities to adapt. These range from technological options to preventive measures. Systematic planning and capacity-building are also needed to reduce the risk of disasters/extreme events and raise the resilience of communities to increasing frequency of extreme events such as droughts, floods and tropical cyclones.

Tentative Objectives

- ☐ To assess climate change impacts on forests for the provisioning, regulating, cultural and supporting services of ecosystem
- ☐ To assess climate change impacts on livelihood and how they affect the use or consumption patterns of ecosystem services
- ☐ To assess the change of corresponding response behaviour or consumption or provision patterns under climate change impacts

8.2.10 REDD plus pilot studies for climate change mitigation

Degradation and conversion of forests in general, and tropical forests in particular, to other land uses are major causes of GHG emissions besides fossil fuel burning. It, therefore, becomes imperative to address deforestation as part of an integrated strategy to reduce global GHG emissions. India has a strong policy framework focusing on conservation of its forests. Forest (Conservation) Act, 1980 has put restrictions on routine diversion of forest land. Also, the mechanism of Joint Forest Management, facilitating greater participation of local communities has promoted regeneration and reforestation of forest land (Rawat and Kishwan, 2008).

A well designed and governed REDD plus has the potential to provide significant opportunities to positively affect forest-dependent livelihoods by:

- Encouraging governments to secure and formalise land tenure for forest dwellers (so that those closest to the resource have positive incentives for conservation)
- ☐ Generating revenue that governments could direct to social services in rural areas like health care centres, schools, water systems, etc
- Creating new income streams for forest dwellers if they are sub-national sellers in carbon markets, participants in conservation payment programmes, recipients of carbon fund distributions, or monitors of forest areas
- Maintaining forests' regulating ecosystem services, flood control and disease prevention, which may enhance adaptive capacity in a changing climate, where risks of extreme weather and disease are projected to increase
- ☐ Maintaining forests' provisioning ecosystem services (fuelwood, medicine, food), which may also help buffer communities from the shocks of reduced agricultural yields that may occur due to climate change

Tentative Objectives

- ☐ Identification of suitable regions at sub-national level for implementing REDD plus pilot studies
- Capacity building and awareness of REDD plus participating communities on REDD plus actions
- Developing a reference level for REDD plus pilot areas and safeguard information systems for REDD-plus
- Quantification of carbon accrued or saved by the REDD plus actions
- ☐ Implementing a REDD plus pilot with active community involvement
- ☐ Developing a protocol for passing of financial benefits accrued to communities

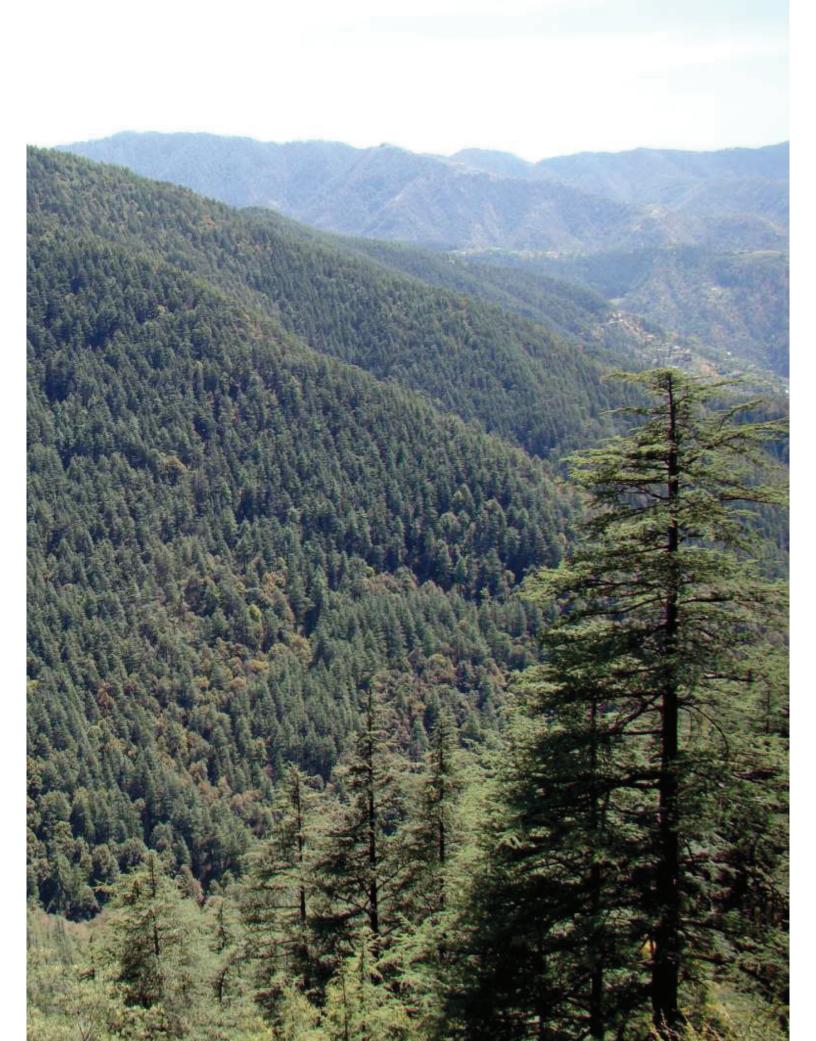
8.2.11 Eco-rehabilitation of mined out areas for mitigation of climate change through enhanced carbon sink

Most of mining leases occur in forested areas and thus damage the forest ecosystem. Mining is an environmentally damaging activity causing large scale deforestation and forest degradation, destruction of wildlife and other natural resources, and also causing ecological problems (depletion of floral and faunal populations, loss of fertile top soil, sliding and erosion, etc.). Mining operations have set aside areas which are very difficult to restore, and which show signs of environmental degeneration. It is estimated that the total land under mining in India is 7,54,861 ha, of which 6,20,372 ha is being mined for major minerals, involving 9131 mining leases; and 0.13 million ha is being mined for coal by the public sector mines (MoEF, 2010).

Mine waste dumps and mined out areas can be transformed into an opportunity for climate change adaptation, carbon sequestration and productivity enhancement for sustainable livelihoods through ecological restoration. Plantation in mined out areas can provide an option for enhancing carbon sinks and mitigate impacts of climate change. The ecological restoration of mined out areas through sustainable techniques/methods/models will check further deterioration of land and will help in conserving biodiversity, soil and water and ultimately mitigate the impact of climate change through sequestrating more carbon in vegetation and soil. Therefore, eco-rehabilitation of mined out areas of the whole country is required in current scenario of climate change for conserving the biodiversity as well as mitigating the climate change.

Tentative Objectives

- ☐ To determine the extent and impact of mining on forest ecosystem
- ☐ To select the site specific plant species for eco-rehabilitation of mined out areas
- ☐ To rehabilitate the mined out areas through adopting sustainable methods/techniques
- ☐ To monitor the impact of implementation of sustainable eco-rehabilitation methods/techniques in mined out areas on biodiversity and climate change mitigation





WAY FORWARD

9.1 Vulnerability of Indian forests to climate change and adaptation measures

India has reason to be concerned about climate change. A majority of its population depends upon climatesensitive sectors like agriculture and forestry for livelihood. Any adverse impact on water availability due to recession of glaciers, decrease in rainfall and increased flooding in certain pockets would threaten food security, cause dieback of natural ecosystems including species that sustain the livelihood of rural households, and adversely impact the coastal system due to sea-level rise and increased extreme events. This aside, achievement of vital national development goals related to other systems such as habitats, health, energy demand and infrastructure investments would be adversely affected.

India is endowed with diverse forest types ranging from tropical wet evergreen forests in the North East and the South West, to tropical dry thorn forests in the central and western India, and temperate and alpine forests in the Himalayan region. The forests of India are divided into 16 major types comprising 221 subtypes. Forests in India are already subjected to multiple stresses, including over-extraction, insect outbreaks, livestock grazing, forest fires, and other anthropogenic pressures. Climate change will be an additional stress. Forests are likely to be more vulnerable to climate change. The impacts of climate change on forests in India are assessed in the India's Second National Communication to the UNFCCC (MoEF, 2012), based on the changes in area under different forest types, shifts in boundary of forest types and changes in the net primary productivity has been predicted. This assessment was based on: (i) spatial distribution of current climatic variables, (ii) future climate projected by relatively high-resolution regional climate models for two different periods for the A1B climate change scenario, and (iii) vegetation types, NPP and carbon stocks as simulated by the dynamic model IBIS v.2 (Integrated Biosphere Simulator). The vegetation distribution simulated by IBIS for baseline, and A1B scenario in the simulation grids illustrates an expansion of tropical evergreen forests in eastern India plateau in the A1B scenario. Similar trend is observed in the Western Ghats. It is interesting to note that there is almost no vegetation type change in the North-east. Further, there is a slight expansion of forests into the western part of central India.

The forests of India are a source of fuel and fodder for rural people, an industrial input for a growing economy, a habitat for thousands of plant and animal species, a sink for CO₂ emissions, and a protective cover for their soils. An effective Forest (Conservation) Act, 1980, further strengthened in 1988, stipulating a massive afforestation programme, establishment of reserves, and re-vegetation of degraded lands through joint forest management and people's participation helped India to conserve its forests and put a check on the diversion of forest land to non-forest uses.

9.2 Adaptation measures and strategies

Forest conservation and enhancement are the stated objectives of the national forest policy. Various policy initiatives have resulted in increase in the forest cover and a reduction in the deforestation rate. The National Forest Policy envisages peoples' participation in the development of degraded forests to meet their fuel, fodder, and timber needs, as well as to develop the forests for improving the environment through

Joint Forest Management. India has implemented a large number of progressive policies, programmes, and measures to conserve and develop forests, wildlife, mangroves, and coral reefs, examples being the Forest (Conservation) Act, 1980, the National Forest Policy, 1988, the Wildlife Act, Joint Forest Management, Social Forestry, banning of timber extraction in reserve forests, improved cooking stove programme, and use of biogas to conserve fuelwood. Similarly, there are conservation programmes for mangroves, coral reefs, and lake ecosystems. All these measures have led to some stabilization of the forest area, a reduction in deforestation, and some increase in forest cover, significantly contributing to the conservation of the forest carbon sink. All these preparations will form the adaptation measures for the forest dependent communities against the challenges posed by climate change.

There is a need for developing and implementing adaptation measures to enable forest ecosystems to cope with climate risks. Many "win-win" or "no-regret" adaptation practices could be considered for implementation. A few pilot adaptation projects could be launched, incorporating the "win-win" adaptation practices, particularly in the most vulnerable regions identified in the Second National Communication (MoEF, 2012). A few examples of adaptation practices include: (i) Modifying the forest working plan preparation process and incorporating the likely impacts due to projected climate change, (ii) Initiating research on adaptation practices, covering both conservation and forest regeneration, (iii) Linking Protected Areas and forest fragments, (iv) Anticipatory planting of species along the altitudinal and latitudinal gradient, (v) *In situ* conservation, (vi) Adopting mixed species forestry in all afforestation programmes, (vii) Incorporating fire protection and management practices and implementing advance fire warning systems.

9.3 India's National Action Plan on Climate Change

India's development plans are crafted with a balanced emphasis on economic development and environment. The planning process is guided by the principles of sustainable development with a commitment to a cleaner and greener environment. India's National Action Plan on Climate Change is guided by the principles of sustainable development and aligns the environmental and economic objectives. Broadly, the NAPCC is based on the following principles:

- Protecting the poor and vulnerable sections of society through sustainable development strategies that are sensitive to climate change
- Achieving national growth targets by means that enhance ecological sustainability
- ☐ Devising an efficient and cost-effective strategy for demand-side management
- Deploying appropriate mitigation and adaptation technologies extensively and at an accelerated pace
- □ Promoting sustainable development through innovative and new forms of market, regulatory and voluntary mechanisms
- ☐ Effecting implementation of various policies through unique linkages with civil society, local governments and public-private partnerships
- ☐ Welcoming international cooperation for research, development, sharing and transfer of technologies driven by external funding and facilitating a global Intellectual Property Rights regime for such a technology transfer under the United Nations Framework Convention on Climate Change

9.4 Synergy among various mission of the National Action Plan on Climate Change

Proposed action under various missions of the NAPCC can be synergized to get a multiplier effect of the various Missions. Various actions under Green India Mission have the potential to substantiate the objectives of other national Missions on climate change.

Managing the Himalayan ecosystem sustainably is critical not only for preserving its pristine beauty and spectacular landscapes, but also for ensuring the ecological security of the entire Indian sub-continent. The guidelines issued in theNational Mission on Sustainable Himalayan Ecosystems (NMSHE) document cover a wide variety of issues - including urbanization, tourism, water security, energy, forest management and infrastructure. Under the NMSHE, two thirds of the geographic area of the Indian Himalayan Region (IHR) is targeted to be under forest cover, with the local communities playing an important part in its maintenance. Dovetailing mission objectives of NMSHE and GIM can lead to greater synergy of these two important National Missions under NAPCC where forestry has important role to play for mitigation and adaptation to Climate Change (DST, 2010).

Urbanisation is taking place at a fast rate in India. Urban forestry has the potential to be promoted under GIM. The primary objective of the GIM is to Increase forest/tree cover on 5 million ha of forest/non-forest lands and improved quality of forest cover on another 5 million ha (a total of 10 million ha). Under greening of areas with no forest cover, the urban forestry programmes with active participation and collaboration of government departments, educational institutions, municipal bodies, local residents may also be undertaken for greening of the urban areas under the National Mission of Sustainable Habitat (MoEF, 2010).

The projected climate change is likely to impact the existing forest ecosystems, biodiversity and biomass production. National Mission on Strategic Knowledge on Climate Change (NMSKCC) needs to strengthen scientific capabilities to assess likely impacts of climate change on forests and other natural ecosystems (mangroves, coral reefs, wetlands, montane grasslands) as such loss of biodiversity could be irreversible. The National Mission on Strategic Knowledge on Climate Change (NMSKCC) can also include research on various aspects of forest and climate change such as modelling studies and research for predicting general trends related to climate change in respect of forest ecosystems. Short and long term research and studies to understand behaviour of individual plant species as also of plant communities are equally important. Similarly, research to study potential of different species, forest type groups and vegetation communities to sequester carbon would be needed to plan and implement strategies capable of capturing optimum carbon from atmosphere.

Research programmes on adaptation and vulnerability also needs to the underscored. Currently, there is very little research on adaptation. There is a need for initiating research on developing and evaluating adaptation practices and strategies to enhance the resilience of the forest ecosystems. As India is steering one of the largest global effort of afforestation through its Green India Mission, there is a need to reduce the vulnerability of the afforestation programme to projected climate change. Appropriate adaptation practices may have to be developed and incorporated in Green India Mission.

9.6 Forestry contribution to climate change mitigation actions:

India's forest and tree cover accounts for about 24% of the total geographical area of the country. Over the past decades, national policies of India aimed at conservation and sustainable management of forests have transformed India's forests into a net sink of CO₂. From 1995 to 2005, carbon stocks stored in our forests have increased from 6244.78 to 6621.55 million tonnes (mt) registering an annual increment of 37.68 mt of carbon = 138.15 mt of CO₂eq. This annual removal by forests is enough to neutralize 9.31% of our total annual emissions of 2000 (Kishwan et al., 2009). In 1994 India's forests were a net source of GHG emissions contributing 1.16% of the total national emissions as reported in its first National Communication to the UNFCCC (MoEF, 2004) while Second National Communication (SNC) reported a net sink of 17.10% for the year 2000 (MoEF, 2012). INCCA (2010) reported a net sink of 9.29% for the year 2007.

With its focus on sustainable management of forests, afforestation and regulating diversion of forest land for non-forest purposes, India has been successful in improving carbon stock in its forests by as much as 10%

amounting to about 600 million tonnes of carbon for the decade ending in 2004 (FSI, nd). In mitigating climate change, conservation of forest carbon stocks, sustainable management of forests and afforestation and reforestation are therefore as important as preventing deforestation and degradation.

Practices for management of wildlife protected areas and other specifically conserved forest areas resulting in saving and maintenance of existing forest carbon stocks can be grouped under 'conservation forests'. These are the best areas for carbon service. Other forest areas which are subject to harvests and are managed according to prescribed working or management plans can be put under 'sustainably managed forests'. Conservation and sustainable management of forests over a period of time would not only result in maintaining existing forest carbon stocks, but would also affect an increment in their quantum due to natural process of growth of forest vegetation. Use of improved and more energy efficient wood-burning cooking stoves can also help in saving wood biomass and thus contribute towards conservation of forests. Enhancement of forest carbon stocks can be achieved by increasing the forest area, or the carbon density and/or increasing the pool of carbon stored in a given forest or wooded area. In this case, the basic actions would comprise afforestation, reforestation, agroforestry, and energy plantations (fuelwood and biodiesel). With effective implementation of GIM and various interventions proposed by the Planning Commission (2014), a nation vide programme in India can offset 5-10% of its national GHG emission in next 10 years.

9.7 Operationalization of REDD plus in India

National REDD-plus policy and action plan: Keeping in view the progress made under the agenda of REDD plus in the international negotiations, Government of India has initiated preparation of a REDD plus policy for the country. India's national strategy or action plan aims at enhancing and improving the forest and tree cover of the country thereby enhancing the quantum of forest ecosystem services that flow to the local communities. The services include fuelwood, timber, fodder, NTFP and also carbon sequestration. It is underlined that in the Indian context, carbon service from forests is one of the co-benefits and not the main or the sole benefit. Initiatives like Green India Mission and National Afforestation Programme (NAP), together with programmes in sectors like agriculture and rural development would add or improve 1 million ha of forest and tree cover annually in our country.

Institutional mechanism for REDD plus at national level: The Government of India has established a REDD plus Cell in the Ministry of Environment, Forest and Climate Change having the task of coordinating and guiding REDD plus related actions at the national level, and to discharge the role of guiding, and collaborating with the State Forest Departments to collect, process and manage all relevant information and data relating to forest carbon accounting. National REDD plus Cell would also guide formulation, development, funding, implementation, monitoring and evaluation of REDD plus activities in the States. The Cell will assist the MoEFCC and its appropriate agencies in developing and implementing appropriate policies relating to REDD plus implementation in the country.

Initiating REDD plus pilots: A few isolated REDD plus pilot projects have already been initiated in India. Subject to availability of finance from national, international (bilateral or multilateral) or alternative sources, India intends to launch pilot projects, one each based on the concept of Reducing Emissions from Deforestation, Reducing Emissions from Forest Degradation, conservation of forest carbon stocks, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks respectively, to understand the intricacies of maintaining baseline forest carbon stocks, forest carbon stocks changes, and forest carbon accounting. These projects will be taken at locations that cover different forest types and socio-geographic regions of the country. For example, project on Reducing Emissions from Deforestation, Reducing Emissions from Forest Degradation can be taken in North-eastern States, conservation can be taken up in the Western Himalayan region comprising States of Uttarakhand, Himachal Pradesh and Jammu and Kashmir, whereas

Western Ghats should be suitable to test the concept of SMF. EFCS project can be taken up in any of the States registering increase in forest and tree cover according to latest India State of Forest Report.

9.8 Education, training and public awareness

The National Mission on Strategic Knowledge for Climate Change (NMSKCC) was conceived to build a vibrant and dynamic knowledge system that would inform and support national action for responding effectively to the objectives of sustainable development. In order to further facilitate the implementation of the National Action Plan, the National Knowledge Commission was also identified as being an important component regarding climate change education. It is envisaged that the Commission would carry out the following activities.

Land use, land-use change and forestry sector - constraints and needs: The LULUCF sector in India has the potential to be a major source or sink of CO, in the future. The uncertainty in the estimates of inventory in the LULUCF sector is shown to be higher as compared to other sectors such as energy transformation, transportation, industrial processes, and even agriculture. The availability and access to information on activity data, emission coefficients, and sequestration rates in the LULUCF sector in India are limited, and the uncertainty of the data is high, as in most countries. Thus, there is a need for improvement in the information generation processes for the inventory so as to reduce the uncertainty involved in the estimation of GHG inventory in the LULUCF sector. Various agencies like ISRO, NRSC, FSI, ICFRE and IISc need to work together to reduce uncertainty of estimates in this sector.

Identification of specific research themes related to adaptation and mitigation aspects of forests: Our present state of knowledge on the relationship between climate and plant performance is grossly inadequate for the purpose of modelling future climate change impacts. Research in the some of the areas mentioned in the text elsewhere is thus a key prerequisite for coming up with robust mitigation and adaptation strategies in this sector. Singh and Rawat (2013) analysed the current research and capacity building needs in the Forest and Climate Change in India.

Climate-related capacity needs in forestry: India needs massive capacity building programmes in forestry sector to cope with the challenges of climate change mitigation. Singh and Rawat (2013) stressed for capacity building programmes on various aspects of climate change mechanisms for enhancing the capabilities of forestry professionals and other stakeholders at national, state and local levels. Strengthening local community institutions through 'Gram Sabhas' and building a cadre of rural youth, strengthening forest departments and other partner agencies are required for an all inclusive approach in climate programmes and projects. The country's capacity to assess and apply adaptation and mitigation measures in forestry is weak at two levels: national institutional frameworks and adaptive capacity of local populations to climate change and variability. To implement national climate change and forest policies, there is need for in-depth knowledge of appropriate methods and tools as well as awareness of available funding mechanisms, such as the carbon market and adaptation funds and Green Climate Fund (GCF) established under the UNFCCC. Extension services will need to be strengthened substantially in order to address adaptation and mitigation for them to provide an efficient interface between policymakers and the forest community. Recognizing that climate change will alter many existing equilibriums, socio-economic dynamics must be considered, and the role of all the partners may need to be re-examined or redefined (MoEF, 2012).



REFERENCES

- Chaturvedi, R.K., Tiwari R. and Ravindranath, N.H. (2008). Climate change and forests in India. International *Forestry Review*, 10 (2):256-268.
- Chaturvedi, R.K., Gopalakrishnan, R., Jayaraman, M., Govindasamy Bala, G., Joshi, N. V., Sukumar, R., and Ravindranath, N.H. (2010). Impact of climate change on Indian forests: a dynamic vegetation modeling approach, Mitigation and Adaptation Strategies for Global Change, 16:119–142.
- Chhabra, A. and Dadhwal, V.K. (2004). Assessment of major pools and fl uxes of carbon in Indian forests. *Climatic Change*, 64(3): 341–360.
- Chhabra, A., Parila, S. and Dadhwal, V.K. (2002). Growing stock based forest biomass estimate of India. Biomass and Bioenergy, 22:187-194.
- Dadhwal, V.K. and Nayak, S.R. (1993). A preliminary estimate of biogeochemical cycle of carbon for India. Science and Culture, 59 (1/2): 9-13.
- Dadhwal, V.K. and Shah, A.K. (1997). Recent changes (1982-1991) in forest phytomass carbon pool in India estimated using growing stock and remote sensing based forest inventories. Tropical Forestry, 13:182-188.
- Datta, P. (2006). "Urbanisation in India". In: European Population Conference on Regional and Sub-Regional Population Dynamic Population Process in Urban Areas, 21-24 June 2006 (http://www.infostat.sk/vdc/epc2006/papers/epc2006s60134.pdf , Retrieved on 13 June 2012).
- DST (2010). National Mission for Sustaining the Himalayan Ecosystem (Under National Action Plan on Climate Change). Department of Science and Technology, Ministry of Science and Technology, Government of India (http://dst.gov.in/scientific-programme/NMSHE June 2010.pdf).
- Eckman, K., Gregersen, H.M. and Lundgren, A.L. (2000). Watershed management and sustainable development: lessons learned and future directions. In: Ffolliott, Peter F.; Baker Jr., Malchus B.; Edminster, Carleton B.; Dillon, Madelyn C.; Mora, Karen L., tech. coords. Land Stewardship in the 21st Century: The Contributions of Watershed Management; 2000 March 13-16; Tucson, AZ. Proc. RMRS-P-13. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 37-43.
- FAO (2006). Global forest resource assessment 2005: Progress towards sustainable forest management. Forestry Paper 147, FAO, Rome.
- FAO (2012). FAO, Forests and Climate Change. Working with countries to mitigate and adapt to climate change through sustainable forest management. FAO, Rome.
- FSI (nd). Carbon Stock in India's Forests, Forest Survey of India, Dehradun.
- FSI (2009). India State of Forest Report 2009. Forest Survey of India, Dehradun.
- FSI (2011). India State of Forest Report 2011. Forest Survey of India, Dehradun.
- FSI (2013) India State of Forest Report 2013. Forest Survey of India, Dehradun.
- GBPIHED (2010). Governance for Sustaining Himalayan Ecosystem G-SHE Guidelines & Best Practices. G.B. Pant Institute of Himalayan Environment & Development, Kosi, Katarmal, Almora (Uttarakhand).

- Haripriya, G.S. (2003). Carbon Budget of the Indian Forest Ecosystem. Climatic Change, 56: 291-319.
- Heal, G. (2000). *Nature and the Marketplace: Capturing the Value of Ecosystem Services*. Island Press, Covelo, CA.
- Hindustan Times (2007). "Urbanisation in India faster than rest of the world". Hindustan Times. 27 June 2007
- ICFRE (2010). Forest Sector Report India. Indian Council of Forestry Research and Education, Dehradun.
- ICFRE (2013). Soil organic carbon stocks in forests of India. Indian Council of Forestry Research and Education, Dehradun.
- ICIMOD (2009). Assessment of climate change vulnerability of the mountain ecosystems in the Eastern Himalayas: A synthesis report, unpublished report submitted to MacArthur Foundation.
- INCCA (2010). *India: Greenhouse Gas Emissions 2007*. Ministry of Environment and Forests, Government of India.
- IPCC (2000). Land use, land-use change and forestry. *Special Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press., Cambridge, UK, pp.377.
- IPCC (2001). Climate Change 2001: Mitigation, Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, ISBN 0-521-80769-7 (pb: 0-521-01502-2).
- IPCC (2007). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.
- IPCC (2014). Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx, eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- Kishwan. J., Pandey, R. and Dadhwal, V.K. (2009). India's Forest and Tree Cover: Contribution as a Carbon Sink. *Technical Paper No. 130 ICFRE BL 23*, Indian Council of Forestry Research and Education, Dehradun.
- Lal, M. and Singh, R. (2000). Carbon sequestration potential of Indian forests. *Environment Monitoring and Assessment*, 60: 315–327.
- Maikhuri, R.K., Rao, K.S., Patnaik, S., Saxena, K.G. and Ramakrishnan, P.S. (2003). Assessment of vulnerability of forests, meadows and mountain ecosystems due to climate change. *ENVIS Bulletin, Himalayan Ecology*, 11(2): 1-9.
- Manhas, R.K., Negi, J.D.S., Kumar, R. and Chauhan, P.S. (2006). Temporal assessment of growing stock, biomass and carbon stock of Indian forests. *Climate Change*, 74:191-221.
- MoEF (2004), *India's Initial National Communication to UNFCCC*. Ministry of Environment and Forests, Government of India, New Delhi.
- MoEF (2010). National Mission for a Green India (Under The National Action Plan on Climate Change) Draft Document submitted to Prime Minister's Council on Climate Change. Ministry of Environment and Forests, Government of India.
- MoEF (2012). *India's Second National Communication to UNFCCC*. Ministry of Environment and Forests, Government of India, New Delhi.

- MoEFCC (2014). India's Progress in Combating Climate Change. Briefing Paper for UNFCCC COP 20 Lima, Peru. Ministry of Environment, Forest and Climate Change, Government of India.
- Montoya, J.M., Pimm, S.L. and Solé, R.V. (2006). Ecological networks and their fragility. *Nature*, 442: 259-264.
- Mukhopadhyay, D. (2009). Impact of climate change on forest ecosystem and forest fire in India. Climate Change: Global Risks, Challenges and Decisions, IOP Conf. Series: Earth and Environmental Sciences 6.
- Murthy, I.K., Tiwari, R. and Ravindranath, N.H. (2011). Climate Change and Forests in India: Adaptation Opportunities and Challenges. *Mitigation and Adaptation Strategies for Global Change*, 16: 161-175.
- NBA (2008). Biodiversity Management Committees (http://nbaindia.org/text/14/Biodiversity Management Committees.html).
- Negi, J.D.S., Manhas, R.K., and Chauhan, P.S. (2003). Carbon allocation in different components of some tree species of India: A new approach for carbon estimation, *Current Science*, 85(11): 101-104.
- Planning Commission (2011). Climate Change and 12th Five Year Plan. *Report of Sub-Group on Climate Change*, Government of India, Planning Commission, New Delhi.
- Planning Commission (2014). The Final Report of the Expert Group on Low Carbon Strategies for Inclusive Growth, Planning Commission Government of India, New Delhi.
- Raizada, A., Parandiyal, A.K. and Ghosh, B.N. (2003). Estimation of carbon flux through litter fall in forest plantations of India. *Indian Forester*, 129 (7): 881-894.
- Ravindranath, N.H. and Sukumar, R. (1998). Climatic change and tropical forests in India. *Climate Change*, 39: 563–581.
- Ravindranath, N. H., Sudha, P. and Sandhya, R. (2001). Forestry for sustainable biomass production and carbon sequestration in India. Mitigation and Adaptation Strategies for Global Change, 6: 233–256.
- Ravindranath, N.H., Joshi, N.V., Sukumar, R. and Saxena, A. (2006). Impact of Climate Change on Forests in India. *Current Science*, 90(3): 354.
- Ravindranath, N.H., Chaturvedi, R.K. and I.K., Murthy (2008). Forest conservation, afforestation and reforestation in India: Implications for forest carbon stocks. *Current Science*, 95 (2): 216-222.
- Ravindranath, N.H., Chaturvedi, R.K. and I.K., Murthy. (2008). Forest conservation, afforestation and reforestation in India: Implications for forest carbon stocks. Current Science: 216 95 (2): 216-222.
- Ravindranath, N.H. and Murthy, I. K. (2010). Greening India Mission; A Critical Review *Current Science*, 99 (4): 444-449.
- Ravindranath, N. H., Sharma, N., Sagadevan, A., Mathangi Jayaraman, M. and Munsi M. (2012) Climate Change and Its Impacts on Forests of Sikkim. In M. L. Arrawatia, M. L. and Tambe, S. (Eds) Climate Change in Sikkim Patterns, Impacts and Initiatives Published by Information and Public Relations Department, Government of Sikkim.
- Rawat, V.R.S. and Kishwan, J. (2008). Forest conservation-based, climate change-mitigation approach for India. *International Forestry Review*, 10 (2):269-280.
- Rawat, V.R.S. (2012). Implementing REDD Plus strategy and pilot projects in India. *Indian Forester*, 138(3): 307-309.
- Richards, J.F. and Flint, E.P. (1994). Historic land use and carbon estimates for South and Southeast Asia 1880-1980. *ORNL/CDIAC-61*, *NDP-046*, Oak Ridge National Laboratory, Tennessee, USA.

- Roberts, G., Parrotta, J. and Wreford, A. (2009). Current adaptation measures and policies. In: *Adaptation of* Forests and People to Climate Change - A Global Assessment Report (eds. Risto Sappala, Alexander Buck and Pia Katila) IUFRO World Series, vol. 22. International Union of Forest Research Organization, Vienna.
- Roy, B. (2012) "Victims of urbanisation: India, Indonesia and China". Business Standard (15 June 2012).
- The Royal Society (2014). Climate Change: Evidence and Causes. An overview from the Royal Society and the US National Academy of Sciences, 36pp. http://dels.nas.edu/resources/static-assets/execoffice-other/climate-change-full.pdf.
- RRI (2011). South Asia Forest Tenure Assessment. Environment and Climate Series Third, Rights and Resources Initiatives, 12 pp.
- Sathaye, J.A., Makundi, W.R. and Andrasko, K.E. (1995). A comprehensive mitigation assessment process (COMAP) for the evaluation of forestry mitigation options. *Biomass Bioenergy*, 8 (5): 345-356.
- Saxena, N.C. (1996). Forest policy and rural poor in Orissa. Wasteland News, XI (2).
- Sharma, J.V. and Kohli, P. (2014). Analyzing the policy, regulatory and institutional framework for implementation of REDD plus in India. Indian Forester, 140 (12): 1249-1256.
- Sheikh, M.A., Munesh Kumar, Bhat, J.A., Pala, N.A., Rawat, V.R.S. and Todaria, N.P. (2012). Changes in carbon stocks in Indian forests: A historical overview. *Indian Forester*, 138(8): 682-688.
- Singh J.S. and Singh, S.P. (1992). Forests of Himalaya: Structure, Function and Impact of Man. Gyanodaya Prakashan, Nainital, India.
- Singh, K.N. (1978). *Urban Development in India*. Abhinav Publications, New Delhi.
- Singh, S.P. (2002). Balancing the approaches of environmental conservation by considering ecosystem services as well as biodiversity. Current Science, 82: 1331-1335.
- Singh, T.P. and Rawat, V.R.S. (2013). Capacity building in Climate Change for Forest Stakeholders in India. *Indian Forester*, 143(11): 1034-1039.
- Singh, T.P., Rawat, R.S. and Rawat, V.R.S. (2014). Research in climate change adaptation and mitigation aspects of forests in India: an overview. *Indian Journal of Forestry*, 37(1):1-8.
- Spittlehouse, D.L. (2005). Climate change: impacts and adaptation in forestry. In: Climate Change and Forest Genetics, Proc. 29 Meeting, Canadian Tree Improvement Association, part 2, Symposium (O'Neill, G.A. and Simpson, J.D., eds). pp. 43-48.
- UNCCD (2012). Zero Net Land Degradation: A New Sustainable Development Goal for Rio+ 20A report prepared for the Secretariatof the United Nations Convention to combat Desertification Assembly Resolution 42/187, 11 Dec.
- Fact sheet: Climate change science the status of climate change science UNFCCC, (2011a) today, https://unfccc.int/files/press/backgrounders/application/pdf/press_factsh_science.pdf:
- UNFCCC (2011b). India: Views on implementing COP decisions on 'Reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries' (REDD plus)(http://unfccc.int/files/documentation/submissions_from_parties/application/pdf/india _submission_reddplus-strategy.pdf).
- World Bank (2006). Sustainable Land Management: Challenges, Opportunities, and Trade-offs. Agriculture and Rural Development. The World Bank. Washington, DC.





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