Climate Change & Forests; Status of Science , Policy & Research

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Forests and climate change

1. Deforestation and land use change contribute to CO_2 emissions
   – IPCC; 20% of CO_2 emissions
2. Forests provide a large potential to mitigate climate change; REDD, A&R, Bioenergy…
   - IPCC; 15 – 20% of CO_2 emissions
3. Forests will be impacted by climate change and are highly vulnerable to climate impacts
   - Need for adaptation to enable forests to cope with climate change
4. CC could impact Carbon sinks, REDD potential

Forest sector is critical in addressing climate change

Forest sector is very contentious in global negotiations

Issues for Research

1. GHG Inventory from Forestry or LULUCF sector
   – IPCC methods; data and models
2. Mitigation potential assessments at different levels – for land based projects
   1. CDM, REDD+, Forest conservation, A&R, etc
   2. Barriers and policy options to promote mitigation actions
3. Impact of climate change on forest ecosystems, biodiversity and livelihoods
4. Adaptation and resilience enhancement; practices
5. CDM and REDD+; policy and methodological issues
6. International negotiations – India's position on REDD
7. Greening India Mission – Information/Data needs

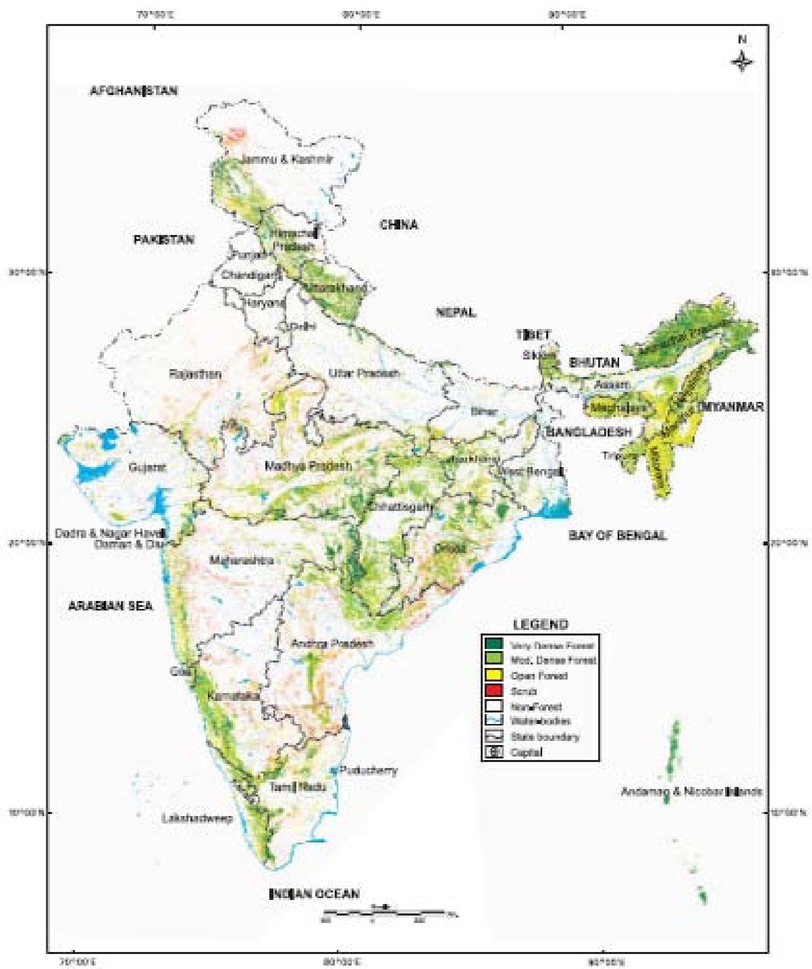
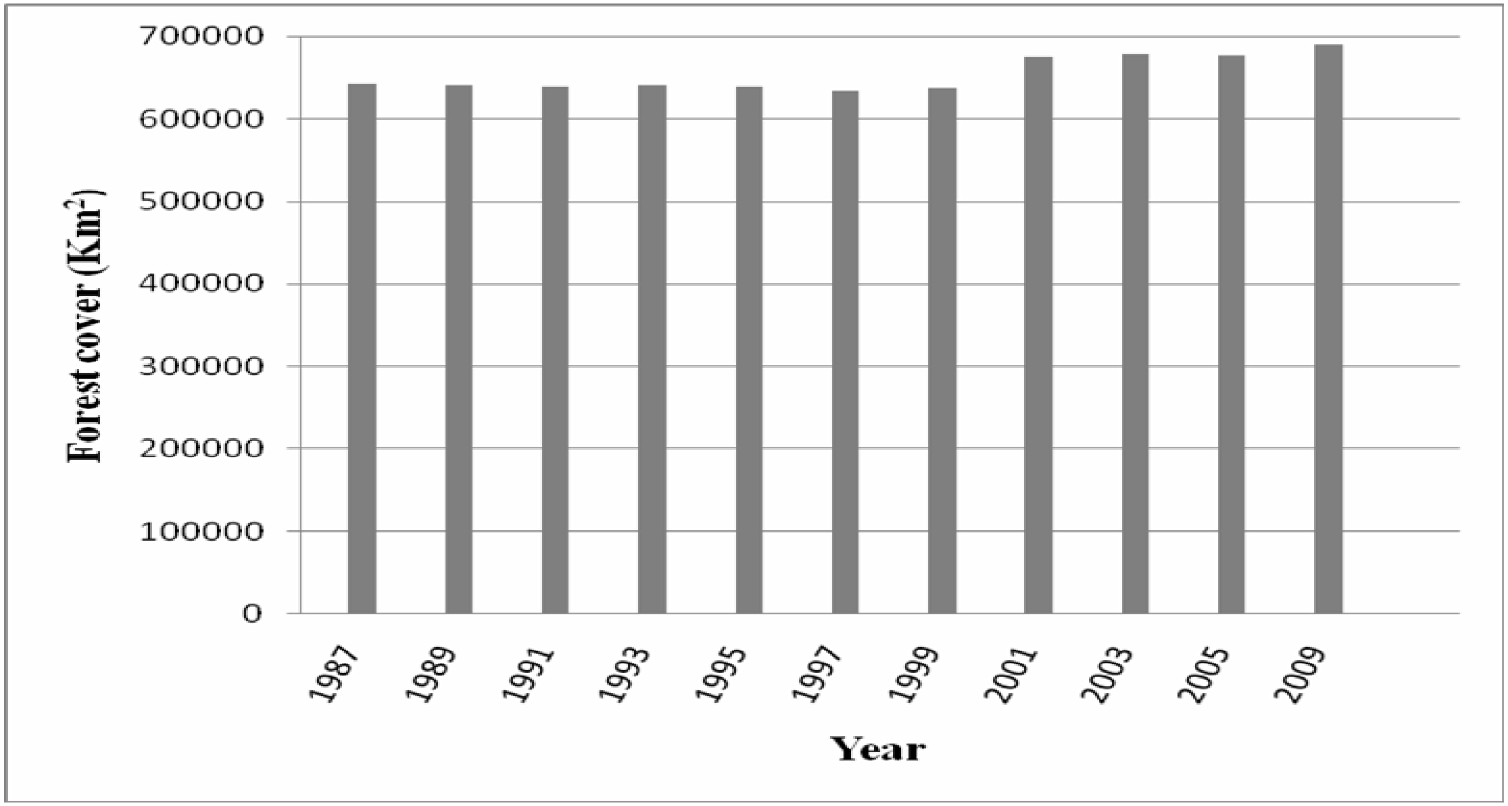


Figure 1: Forest cover map of India of 2007 (FSI, 2009)



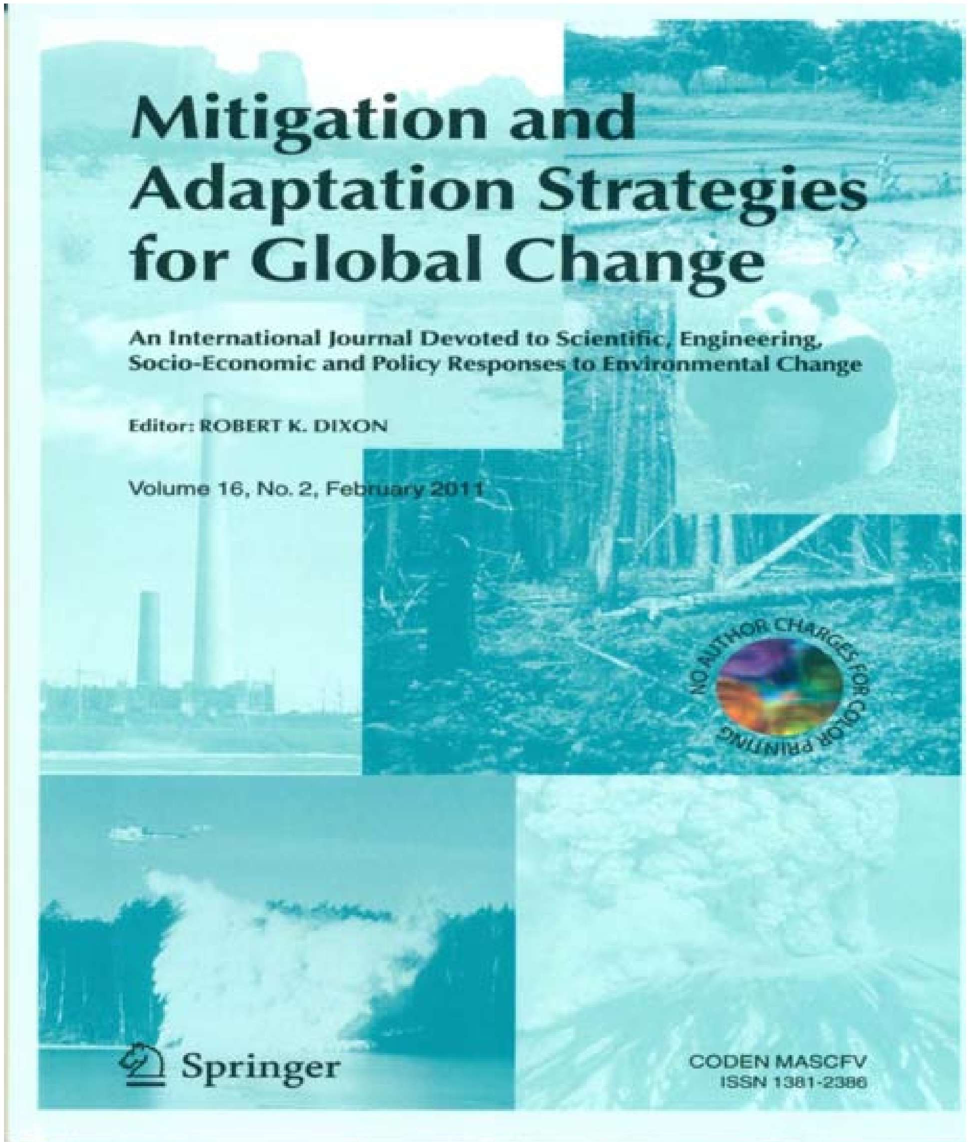
Trends in area under forest over the period 1987 to 2009 (according to FSI reports)

Greening India Mission (GIM)

The Mission aims at addressing climate change by

1. **Enhancing carbon sinks in sustainably managed forests and other ecosystems**
2. **Enhancing the resilience and ability of vulnerable species/ ecosystems to adapt to the changing climate**
3. **Enabling adaptation of forest-dependant local communities in the face of climatic variability.**

Scientific Research & Publication of climate change and Forests



Mitigation and Adaptation Strategies for Global Change

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Special Issue: Climate Change and Forests in India

Guest Editors: N. H. Ravindranath, Ashjorn Aaheim and Jayant Sathaye

Further articles can be found at www.springerlink.com

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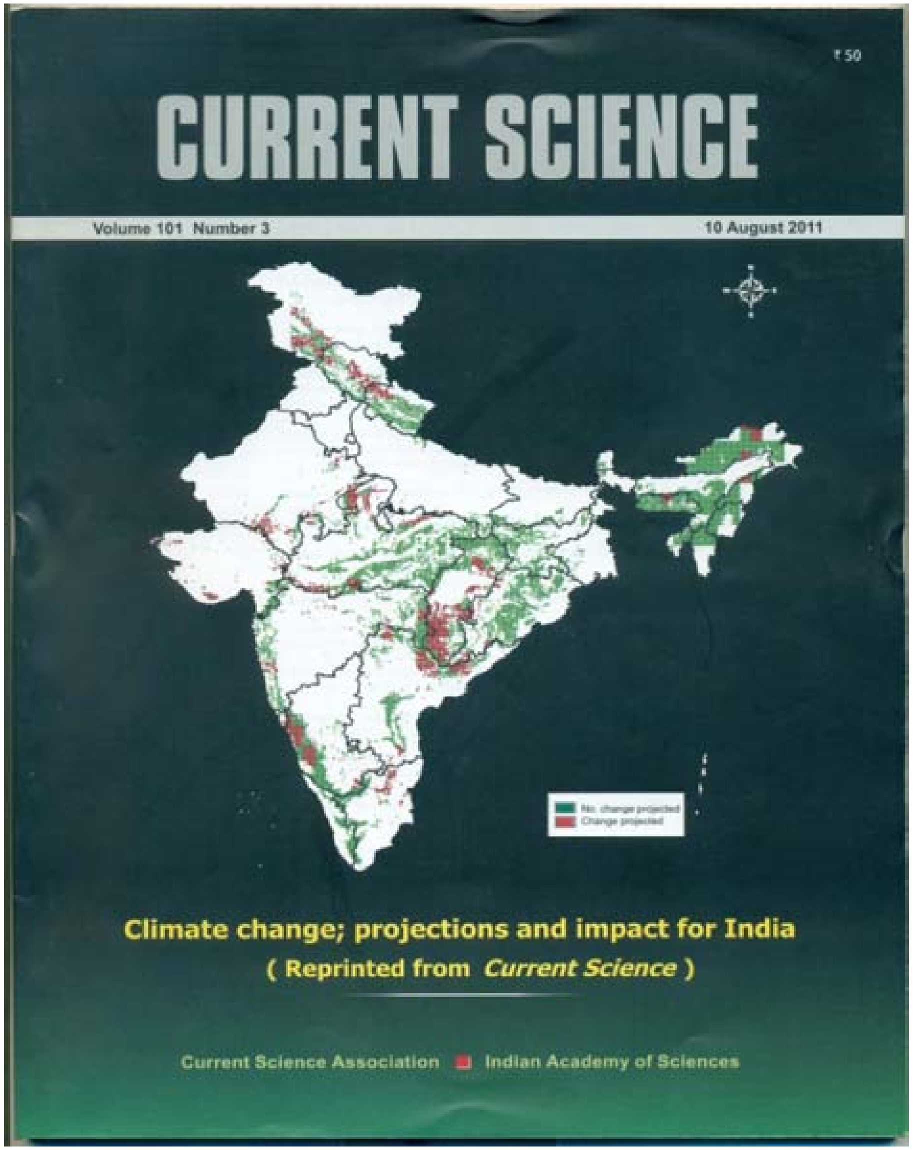
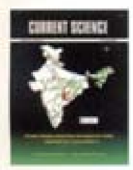


CURRENT SCIENCE

SPECIAL SECTION: CLIMATE CHANGE; PROJECTIONS AND IMPACT FOR INDIA

Guest editors: N. H. Ravindranath, G. Bala and Sobodh K. Sharma



COVER. Vegetation change projected by 2085 A1B scenario.

GHG Inventory from LULUCF Sector

Indian Institute of Science
National Remote Sensing Agency
Forest Survey of India

Greenhouse gas inventory estimates for India

Subodh K. Sharma[1], Asim Choudhury[2], Pinaki Sarkar[2], Subhashis Biswas[2], Anil Singh[2], Pradeep K. Dadhich[3], Ajay K. Singh[2], Suman Majumdar[5], Arti Bhatia[6], Madhu Mohini[7], Rajesh Kumar[8], C. S. Jha[9], M. S. R. Murthy[9], N. H. Ravindranath[10,*], Jayant K. Bhattacharya[11], M. Karthik[11], Sumana Bhattacharya[12] and Rita Chauhan[13]

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This article reports the greenhouse gas emissions of anthropogenic origin by sources and removals by sinks of India for 2007 prepared under the aegis of the Indian Network for Climate Change Assessment (INCCA) (note 1). The emission profile includes carbon dioxide (CO_2), methane and nitrous oxide. It also includes the estimates of hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride at the national level from various sectors, viz. energy, industrial process and product use, agriculture, land-use, land-use change and forestry (LULUCF), and waste. In 2007, emissions were of the order of 2008.67 Tg (note 2) of CO_2 equivalents without emissions from the LULUCF sector. Whereas with LULUCF the emissions were about 1831.65 Tg CO_2 equivalents. The energy sector accounted for 69% of the total emissions, the agriculture sector contributed 23% of the emissions, 5% of the emissions was from the industrial processes and product use, and only 3% of the emissions was attributable to the waste sector. The LULUCF sector on the whole was net sink category for CO_2. The study tracks the improvements made in inventory estimates at the national level through the years, in terms of the expanding coverage of sources, reducing uncertainties and inclusion of new methodologies, including some elements of future areas of work.

Keywords: Anthropogenic origin, emissions, greenhouse gas inventory, IPCC, source and sink.

Introduction

Estimation and reporting of greenhouse gas (GHG) emissions from anthropogenic sources and removals by sinks have become an important activity of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) towards implementation of their commitment under the Convention. This information from the Parties to the Convention helps to ascertain their levels and trends of GHG emissions nationally and determine their respective contribution to the total GHG pool at a global level. The emission inventories are estimated from the sectors such as energy, industrial process and product use, agriculture, land-use, land-use change and forestry (LULUCF), and waste using the Intergovernmental Panel on Climate Change (IPCC) guidelines to develop comprehensive, comparable, transparent and accurate GHG inventories. The comprehensive methodological guidelines were published in 1996 (ref. 1), which was subsequently upgraded in 2006 (ref. 2). In the interim period, Good Practice Guidance (GPG) was published in 2000, covering energy, industrial process, agriculture and waste sectors[3]; the LULUCF sector was covered in the 2003 GPG–LULUCF (ref. 4). The GPG essentially focused on reducing uncertainties in the estimates by incorporating the concepts of key source category analysis, uncertainty analysis, and measures for quality assurance (QA) and quality control (QC).

An inventory of GHG emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) by sources and removal by sinks at the national level using the IPCC 1996 guidelines was first published in 1998 (ref. 5). These estimates indicated that the total CO_2 equivalent

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GHG-INVENTORY GUIDELINES

1. 1996 Revised IPCC Guidelines for GHG Inventory of LUCF sector – NATCOM- I
2. **Good Practice Guidance for LULUCF Sector IPCC 2003 - NATCOM-II**
3. IPCC- GHG Inventory guidelines, 2006
   - AFOLU – Agriculture, Forest and Other land use Sectors

GHG emissions from LULUCF sector for India (Gg) during 2000

Land category	***Sub-category***	***Annual CO_2 emissions/ removals***	***CH_4***	***N_2O***	***Total CO2 eq Emissions***
Forest land	Forest land remaining forest land	-79,918.80	11,600	2,090	-66,228
	Land converted to forest land	**-137,475.00**			**-137,475**
Cropland	Crop land remaining crop land	-15,318.44			-15,318
	Land converted to crop land	-8.87			-9
Grassland	Grassland remaining Grassland	-3,460.77			-3,460
Settlement	Settlement remaining Settlement	-73.13			-73
	Land converted to Settlement	-2.42			-2.42
Total		**-236,257.43**	**11,600**	**2,090**	**-222,567.43**

Limitations of Data on Area, Biomass and Carbon Stock

- **No periodic forest inventory studies in India**
- **Land use change matrix for 6 land categories not available**
- **Carbon pools data not available for different land categories; stocks and changes**
- **Wood extraction; commercial timber and fuelwood extraction data not available**
- **No data on forest degradation**

Mitigation assessment

- **CDM projects**
- **Greening mission**
- **CAMPA**
- **JFM / CFM / Social Forestry / NEAB**
- **REDD plus**
- **IPCC assessments**

Mitigation Options

- Forest Conservation
  - Halting or reducing Deforestation
  - Reducing forest degradation
- Afforestation / Reforestation
- Agro-forestry
- Bio-energy plantations

Models for mitigation assessment

- PROCOMAP
- GCOMAP
- CATIE
- TARAM

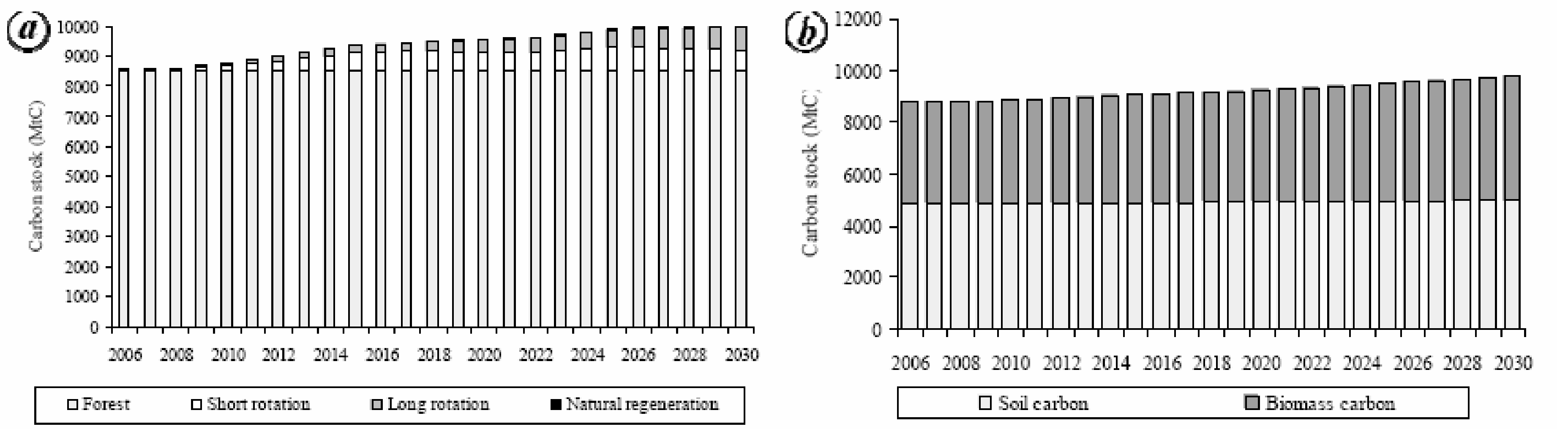

Figure 6. Projected forest carbon stocks. ***a***, Under the current trend scenario for existing forests and area afforested (short- and long-rotation and natural regeneration). ***b***, According to biomass and soil carbon.

Assessment of mitigation potential under changing climate

- **Climate change will impact forest ecosystems, dominant species and net primary productivity**
- **Need to assess the impact of climate change on mitigation potential and forest carbon sink**
  - **Will forests become source from sink**
  - **What happens to REDD+ potential?**

Impact of Climate Change on forest ecosystems and Adaptation Needs

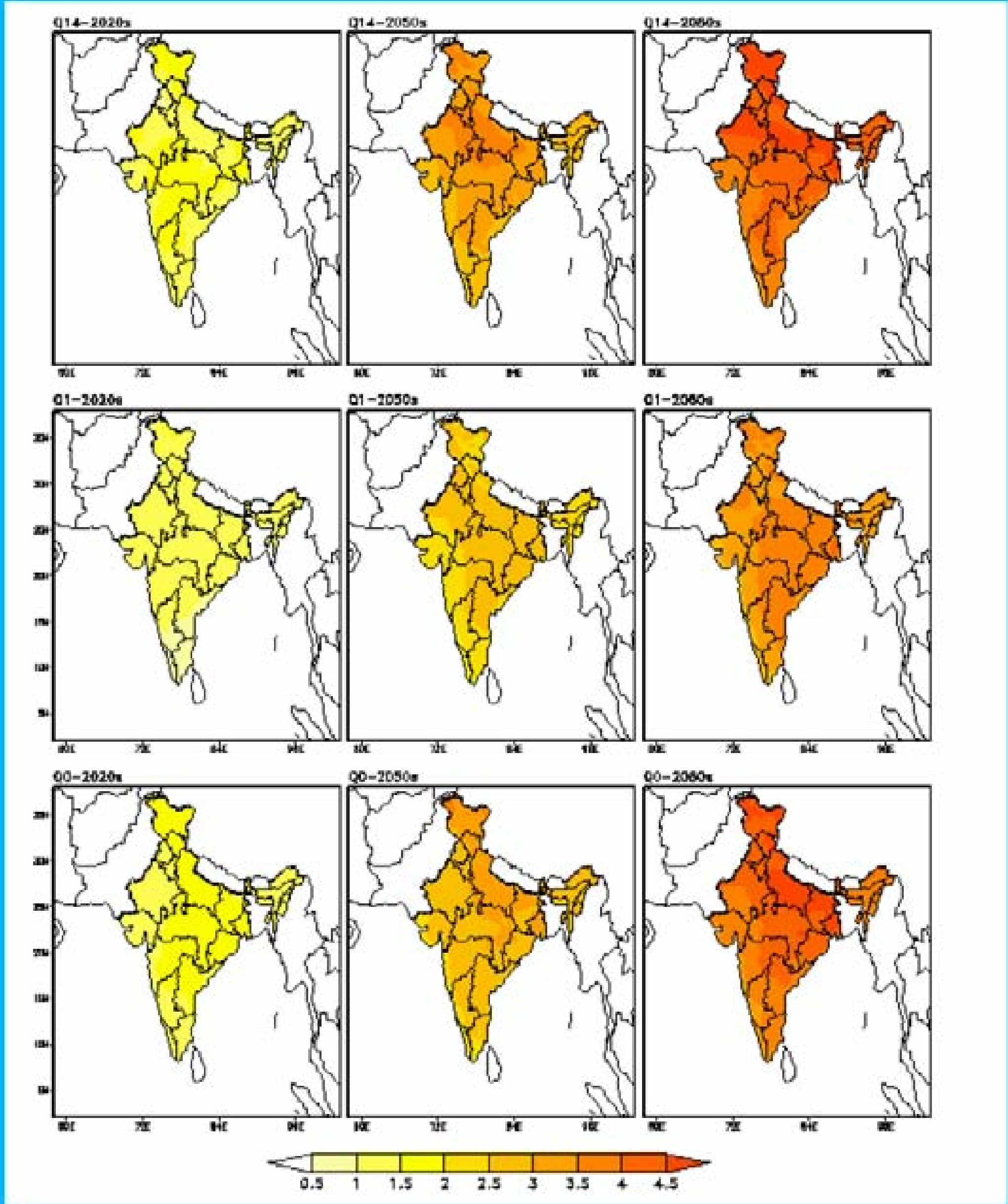

Figure 10: Projected future changes in mean annual surface air temperature (°C) in 2020s, 2050s and 2080s with respect to baseline (1961-1990)

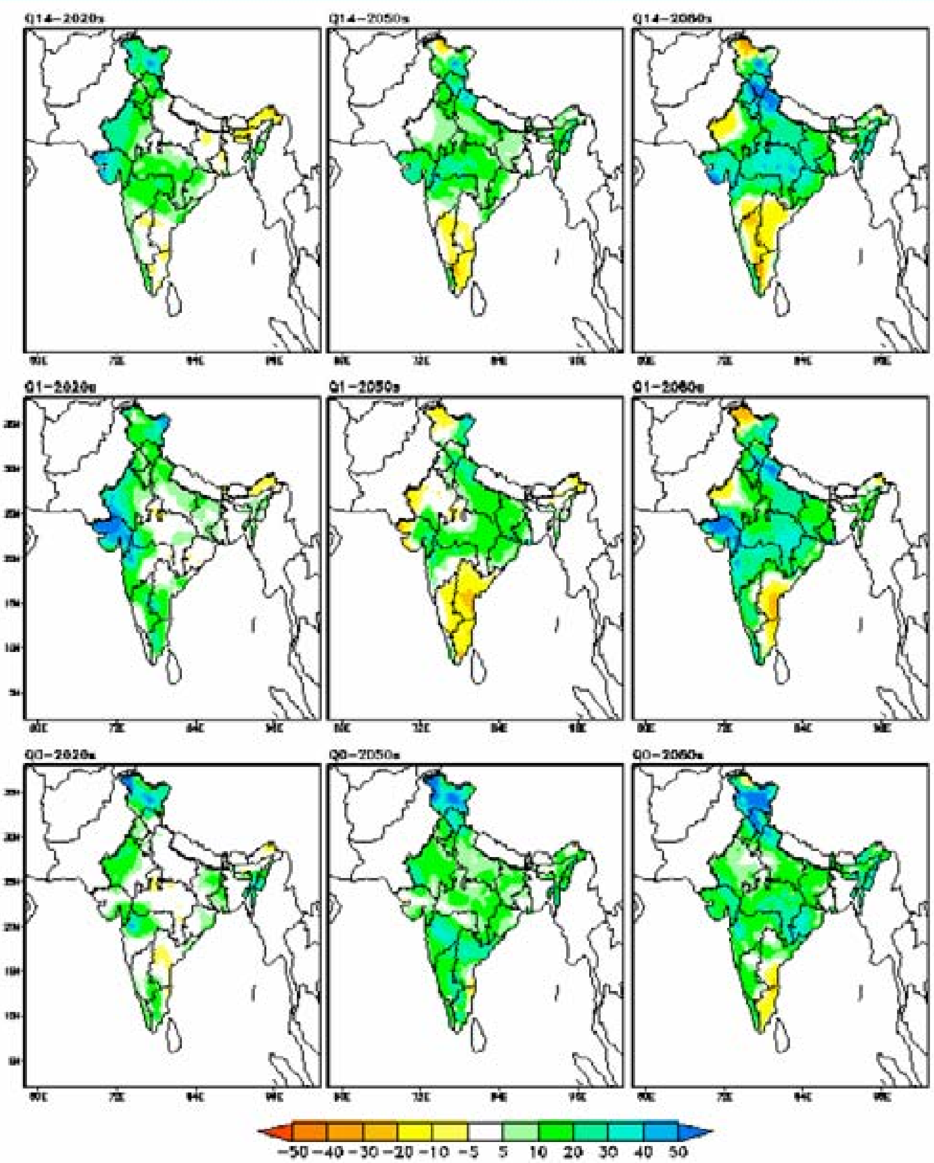

Figure 9: Projected future changes in mean monsoon precipitation (%) in 2020s, 2050s and 2080s with respect to the baseline period of 1961-1990

Impact of Climate Change on Indian Forests

Ranjith Gopalakrishnan, Mathangi Jayaraman, Govindswamy Bala and N.H. Ravindranath

An assessment of the impact of projected climate change on forest ecosystems in India based on climate projections of the Regional Climate Model of the Hadley Centre (HadRM3) and the global dynamic vegetation model IBIS for A1B scenario is conducted for short-term (2021-2050) and long-term (2071-2100) periods. Based on the dynamic global vegetation modeling, vulnerable forested regions of India have been identified to assist in planning adaptation interventions.

The assessment of climate impacts showed that at the national level, about 45% of the forested grids is projected to undergo change. Vulnerability assessment showed that such vulnerable forested grids are spread across India. However, their concentration is higher in the upper Himalayan stretches, parts of central India, northern Western Ghats and Eastern Ghats. In contrast, northeastern forests, southern Western Ghats and the forested regions of eastern India are estimated to be least vulnerable. Low tree density, low biodiversity status as well as higher levels of fragmentation, in addition to climate change, contribute to the vulnerability of these forests. The mountainous forests (sub-alpine and alpine forest, the Himalayan dry temperate forest and the Himalayan moist temperate forests) are susceptible to the adverse effects of climate change. This is because climate change is predicted to be larger for regions that have higher elevations.

Climate is one of the most important determinants of vegetation patterns globally and has significant influence on the distribution, structure and ecology of forests[1]. Several climate vegetation studies have shown that certain climatic regimes are associated with particular plant communities or functional types[2]. It is therefore logical to assume that changes in climate would alter the distribution of forest ecosystems.

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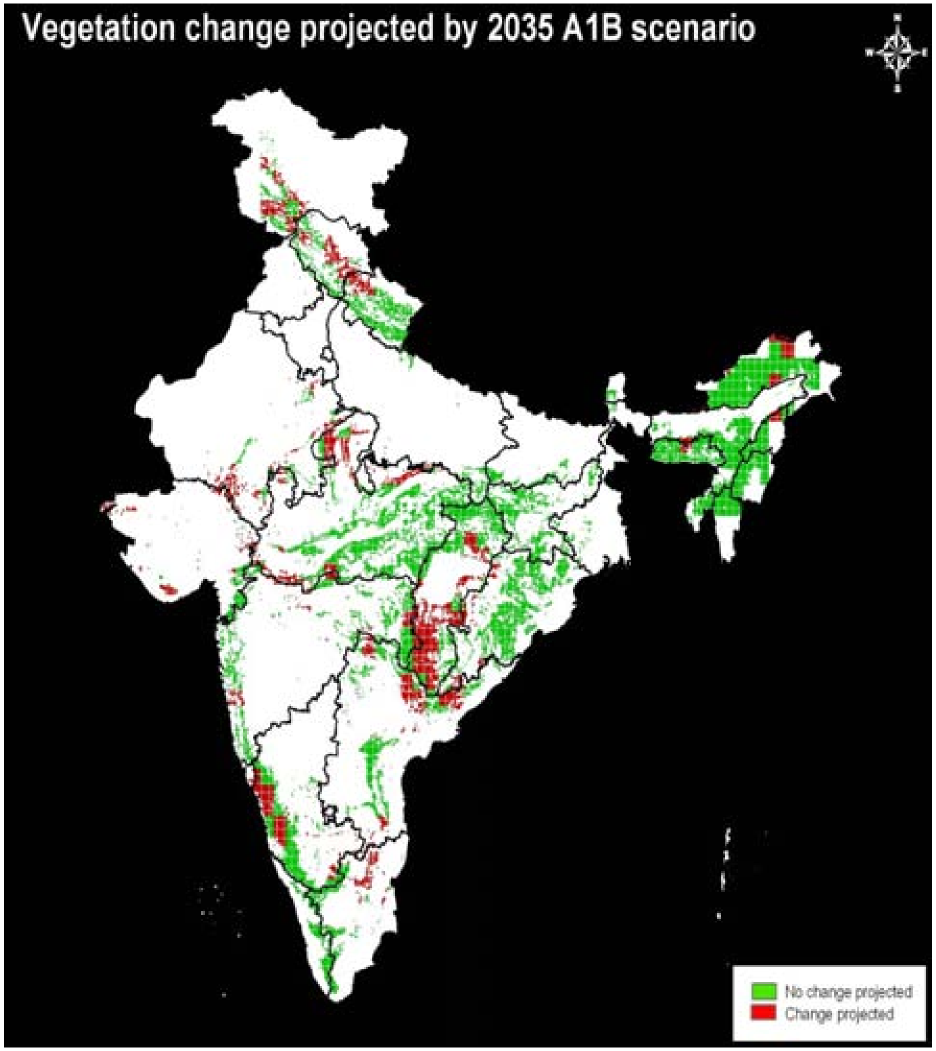
Based on a range of vegetation modeling studies, the IPCC[3] suggests potential forest dieback towards the end of this century and beyond, especially in tropics, boreal and mountain areas[1,5]. The most recent report from International Union of Forest Research Organization[6] paints a rather gloomy picture about the future of the world forests in a changed climate as it suggests that in a warmer world the current carbon regulating services of forests (as carbon sinks) may be entirely lost as land ecosystems could turn into a net source of carbon dioxide later in the century.

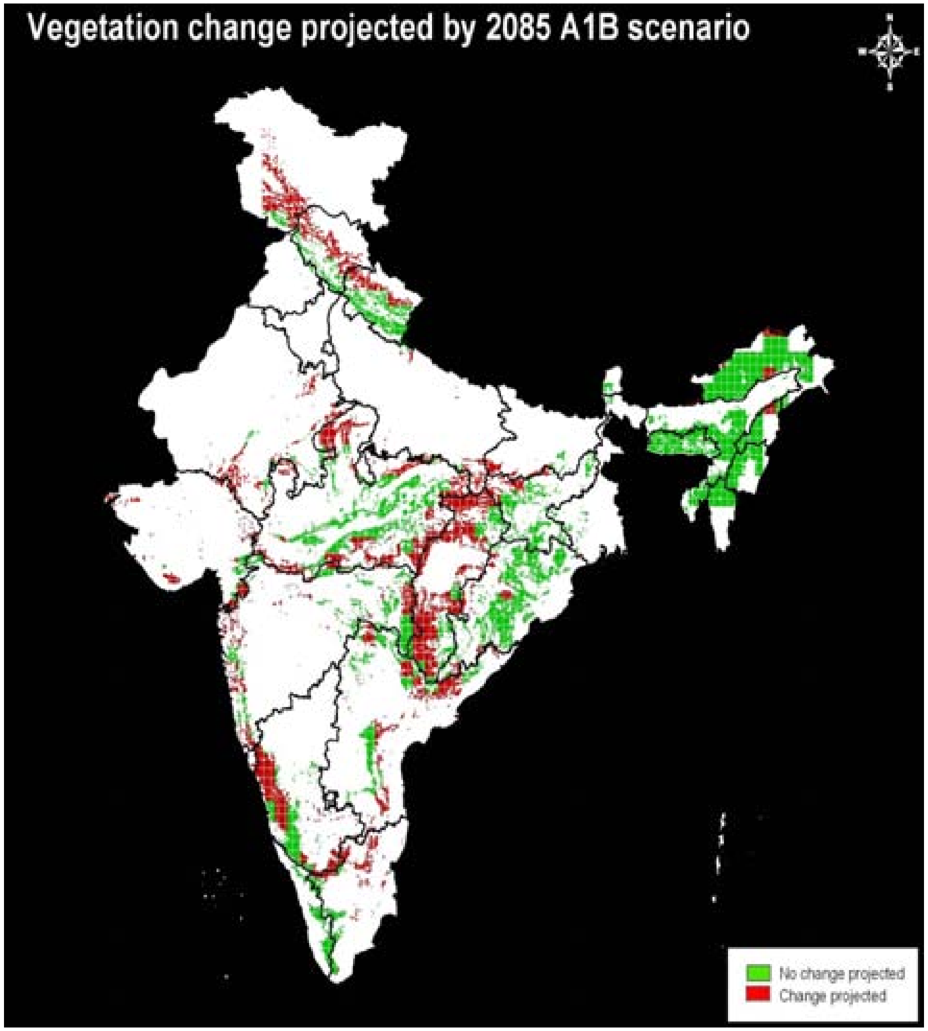
Global Vegetation Model:

1. **BIOME4:** Equilibrium model
2. **IBIS (Integrated Biosphere Simulator):** dynamic global Vegetation Model
3. **Working currently on LPJ & CLM models**

Climate Model: GCM and RCM data from

- Hadley HadRM3 data (50x50 km^2)
- In future other GCMs will be used





Red indicates that a change in vegetation is projected at that grid in the time-period of 2035 & 2085 - under A1B scenario

Green indicates that no change in vegetation is projected by that period.

Percentage of FSI grids projected to undergo change, aggregated by the major forested states – A1B Scenario

State	Number of FSI grids in the state	% projected to change by 2035	% projected to change by 2085
Rajasthan	802	61.22	78.18
Jammu & Kashmir	910	57.03	88.35
Chhattisgarh	3292	48.00	75.85
Himachal Pradesh	838	47.49	65.39
Andhra Pradesh	2288	39.20	51.57
Karnataka	1947	38.37	62.20
Tamil Nadu	776	27.45	47.04
Madhya Pradesh	4432	22.59	48.17
Maharashtra	2197	21.21	45.33
Uttaranchal	1203	19.04	31.92
Arunachal Pradesh	2666	12.27	6.90
Orissa	2564	9.71	13.53
Meghalaya	829	7.96	0.00
Assam	1261	5.23	1.11
Jharkhand	1148	0.00	24.30

Percentage of FSI grids projected to undergo change, aggregated by Champion and Seth forest types – A!B

Forest type (by Champion and Seth, 1968)	Number of FSI grids in type	% projected to change by 2035	% projected to change by 2085
Tropical dry evergreen forest	37	70.27	72.97
Subtropical dry evergreen forest	133	54.14	67.67
Himalayan dry temperate forest	106	52.83	76.42
Himalayan moist temperate forest	1144	52.62	88.02
Subalpine and alpine forest	400	49.75	77.50
Tropical thorn forest	1278	41.39	75.12
Tropical semi evergreen forest	1239	30.67	50.36
Littoral and swamp forest	7	28.57	28.57
Tropical dry deciduous forest	9663	25.62	46.73
Tropical moist deciduous forest	11266	22.63	37.88
Subtropical pine forest	1662	20.64	17.39
Subtropical broad leaved hill forest	192	15.10	15.10
Tropical wet evergreen forest	2862	14.61	14.68
Montane wet temperate forest	940	5.64	0.32

Vulnerability Index and Profile Development

Applicable and necessary for

Greening India Mission

Vulnerability Assessment - Indicators

1. Climate change impact Indicators
2. Bio-physical Indicators
3. Socio-economic Indicators

Criteria & Indicators for Mitigation projects

- **Disturbance index**: **An indication of the human disturbance for a particular forest patch. More the disturbance index, higher the forest vulnerability.**
- **Fragmentation status**: **An indication of how fragmented the forest patch is. More the fragmentation status, higher the forest vulnerability.**
- **Biological richness**: **Indicates the species diversity of the forest patch, a measure of the number of species of flora and fauna, per unit area. *Higher* the biological richness, *lower* the forest vulnerability**
- **Impact of climate change on carbon sinks of forests:** **For estimating climate change impacts, IBIS, which is a dynamic global vegetation model, was used.**

Why Adaptation? When uncertainty in Impact Assessment

- Impacts will be irreversible; e.g.,
  - **loss of biodiversity**
- Inertia in response to changing climate
- Long gestation period in developing & implementation of adaptation practices
- **Waiting for full knowledge – high risk**
- Large ecological, economic and social implications

Focus on "win – win" adaptation options

REDD & CDM

- REDD+ and CDM are likely to become important mechanisms in forestry
- Large opportunities for carbon revenue
- Policy , institutional and financial issues
- Requires rigorous methods for estimating area changes, carbon stock changes
- Requires rigorous monitoring, reporting and verification
- Requires equitable sharing of carbon revenue with local communities

Major methodological issues under REDD / CDM

1. Estimation of deforestation / degradation rates; past, current and projections; spatial and temporal estimates – high accuracy
2. Carbon stock change assessment – REDD
3. Data on biomass & SOC growth rates for different species & forest and plantation types
4. Estimation of emissions from deforestation and degradation
5. Baselines/Issue of setting Reference Emissions Levels
6. Drivers of deforestation and degradation
7. Carbon leakage estimation
8. REDD Monitoring and Verification (MRV)

Research

- Initiate long term monitoring studies vegetation response to CC
- **Enhancing modeling capacity**
- Generate database for forestry CC related analysis and projects
- **Conduct regional level; impact and mitigation studies**
- Developing pilot adaptation project

Addressing Data / Modeling GAPS is most critical for research in the forest sector