Vulnerability of India’s forest to the changing climate

Forest Status:Based on Status of Forest Report 2015

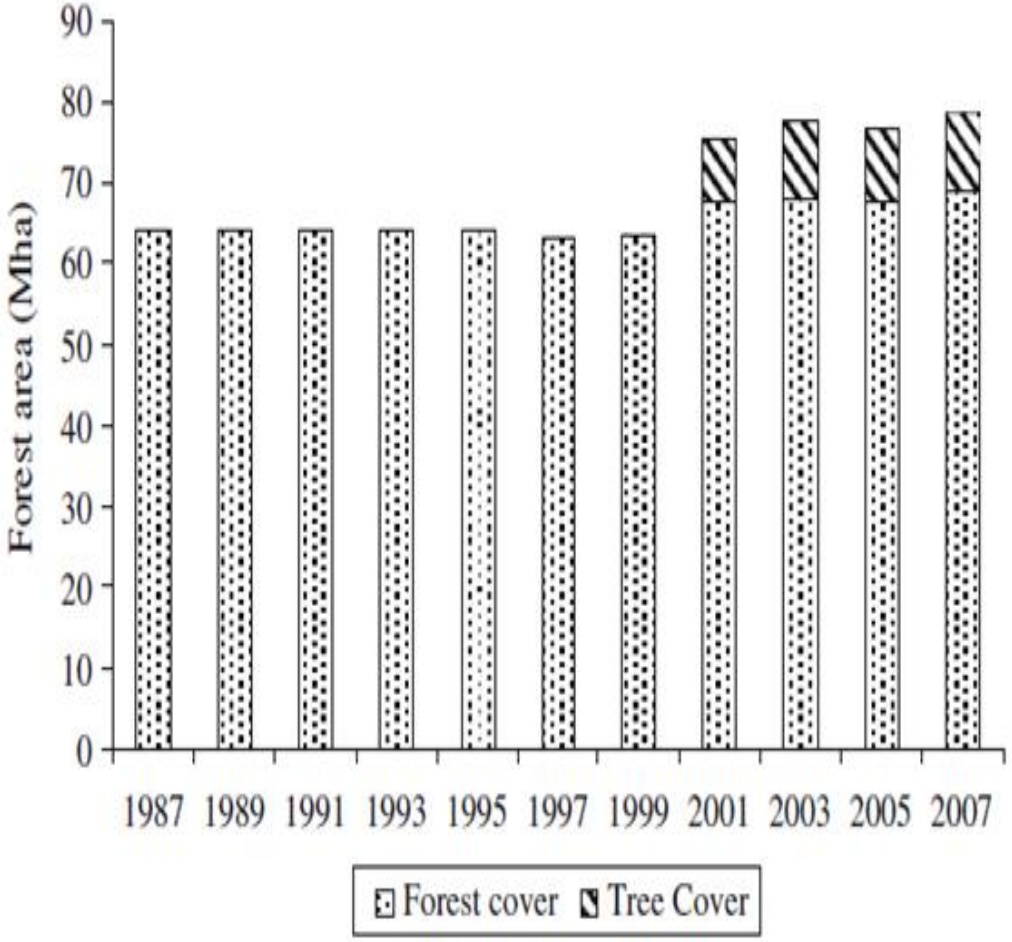
Positives

- Forest and tree cover of India has increased by 5,081 square kilometre (21.34 percent) (3, 775 sq km and 1, 306 sq km) between 2013 and 2015.
- Country's carbon stock increased by 103 million tonnes.
- Very dense forests - 2.61 percent
- Moderately dense forests -9.59 percent
- Open forests -9.14 percent
- Mangrove cover -increased by 112 square kilometre following acute conservation in the Sundarbans and Bhitarkanika forest.
- Increase of 31 sq km of ‘very dense’, moderately dense’ forest decreased by 1,991 sq km while ‘open forests’ have increased by 7,891 sq km, putting the overall increase at 5,871 sq km.

Negatives

- Around 2,510 square kilometre of very dense and mid-dense forests have been wiped out since 2013
- Around 2,254 square kilometre of mid-dense forest cover has turned into non-forest lands in the past two years.
- States of Jammu and Kashmir, Uttarakhand, Meghalaya, Kerala, Arunachal Pradesh, Karnataka and Telangana have suffered huge loss of forest cover

Fig. 1 Trends in area under forest and tree cover (FSI 1989–2009)



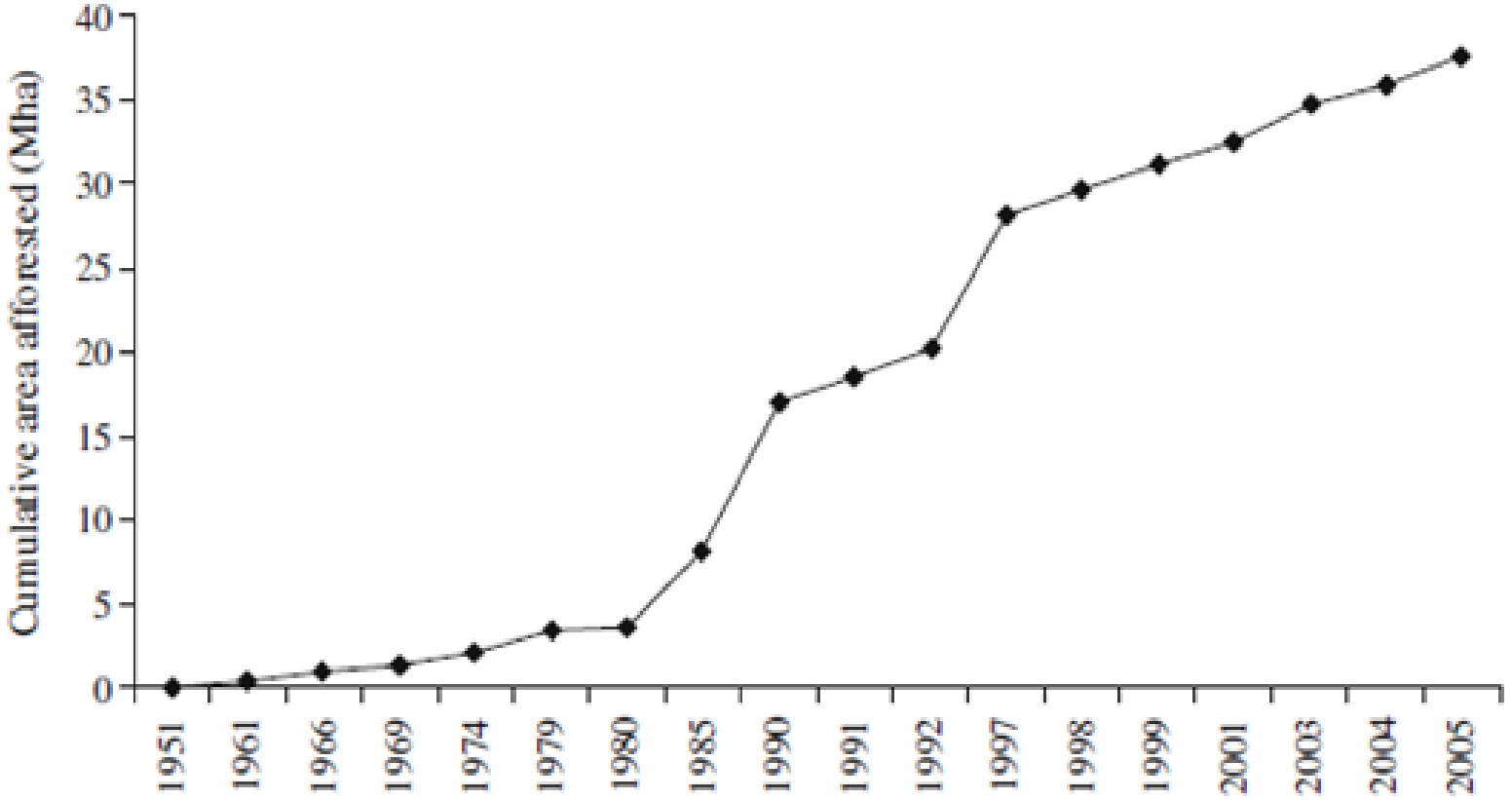


Fig. 4 Cumulative area afforested during 1951 to 2005

Wildlife:

- Home to about 7.6% of all mammalian, 12.6% of avian, 6.2% of reptilian, and 6.0% of flowering plant species
- India contains 172, or 2.9%, of IUCN-designated threatened species. These include the Asian elephant, the Asiatic lion, the Bengal tiger, the Indian rhinoceros, the mugger crocodile, and the Indian white-rumped vulture
- Human encroachment has posed a threat to India's wildlife; in response, the system of national parks , protected areas, biosphere reserves, etc.
- Article 48 and Article 51-A of the Constitution of India
- In 1972, the Wildlife Protection Act came into force

International Conventions

- Convention on International Trade in Endangered Species (CITES)
- World Heritage Convention
- Convention on the Conservation of Migratory Species of Wild Animals (CMS)
- International Whaling Commission

Biodiversity:

- India has some of the most biodiverse regions of the world
- Hosts three of the world's 35 biodiversity hotspots –Western Ghats, the Eastern Himalayas and Indo- Burma
- India is one of the seventeen megadiverse countries i.e. home to about 60-70 % of the world's biodiversity
- Many ecoregions, such as the *shola* forests, also exhibit extremely high rates of endemism; overall, 33% of Indian plant species are endemic

International Programmes and Conventions

- Convention on Biological Diversity
- Ramsar (Wetlands) Convention

GOI-GEF UNDP Projects:

- Mainstreaming coastal and marine biodiversity conservation into production sectors in the east godavari river estuarine ecosystem,AP
- Mainstreaming coastal and marine biodiversity conservation into production sectors in Sindhudurg, Maharashtra
- Developing an effective multiple-use management framework for conserving biodiversity in the mountain landscapes of the High Ranges, the Western Ghats, India

Vulnerability

- Definition by the Working Group II of the Intergovernmental Panel on Climate Change (IPCC): Vulnerability is the degree, to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and its variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Indicators of vulnerability

- Biological Indicators
- Climate Change Impact Indicators
- Socio-economic indicators

Vulnerability

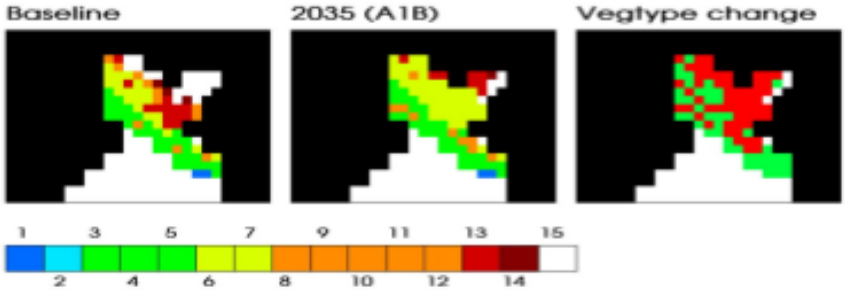
Vulnerability is linked to

- Low tree density and large open forest
- Higher levels of fragmentation,
- Low biodiversity
- Extreme events
- Higher elevations

- The vulnerability index 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.
- IPCC 2007 suggests potential forest dieback towards the end of this century and beyond, especially in tropics, boreal and mountain areas

- During the Working Plan exercise conducted in Timli we observed the vulnerability of the forest to biotic pressures like grazing, lopping, illicit felling, encroachment, fires etc. and natural phenomena like landslides, forest fires, extreme weather conditions etc.
- This could be exacerbated by Climate Change
- For example, Sal seeds have very short viability and thus its regeneration could be adversely effected by global warming and increased incidences of extreme weather phenomenas

Projected Impact of Climate Change over Himalayas in the mid period 2035



-25 out of 65 IBIS grids (39%) are projected to undergo change region by 2030s.

- Sub-Alpine and Alpine and Himalayan Moist Temp forests are Vulnerable

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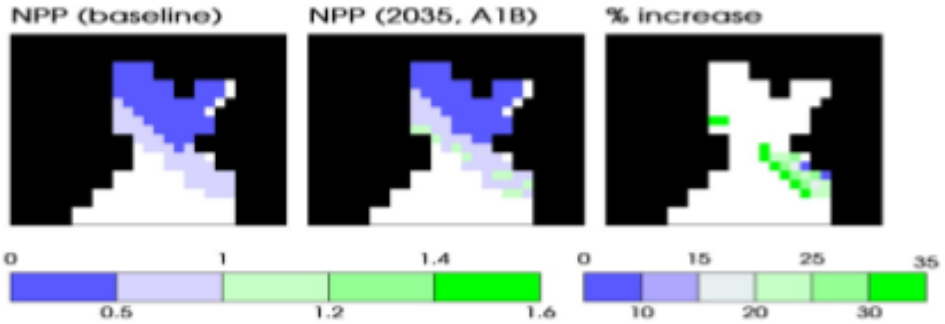


-NPP is projected to increase in the region by about 57% on an average by 2030s

-snow cover is projected to be replaced by vegetation cover.

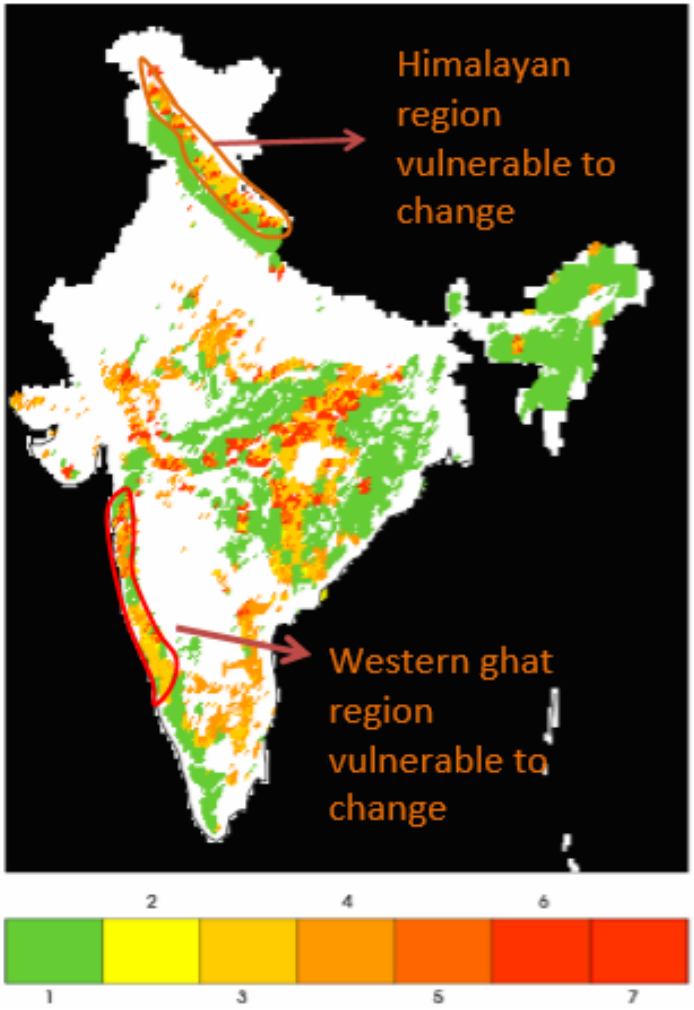
vulnerable vegetation types for the Western Ghats

Champion and Seth type	Number of grids	% of grids as per Champion and Seth classification	Number of grids where vegetation shift is projected
Tropical Wet Evergreen Forest	6	11.11	2
Tropical Semi Evergreen Forest	10	18.52	3
Tropical Moist Deciduous	15	27.78	3
Tropical Thorn Forest	13	24.07	2
Tropical Dry Deciduous	10	18.52	0
Total	54	100.00	10

vulnerable vegetation types for the coastal regions

Champion and Seth type	Num of grids	% of grids as per C &S classification	Number of grids where vegetation shift is projected	% of grids where vegetation shift is projected
Tropical Thorn Forest	**41**	**43.16**	**18**	**43.90**
Tropical Dry Deciduous	9	9.47	3	33.33
Littoral And Swamp Forest	3	3.16	1	33.33
Tropical Dry Evergreen Forest	7	7.37	2	28.57
Tropical Moist Deciduous	**28**	**29.47**	**5**	**17.86**
Tropical Semi Evergreen Forest	7	7.37	0	0.00
Total	95	100.00	29	30.53

Distribution of forest vulnerability index for FSI forested grid points (A2 Scenario for 2085)



Red is most Vulnerable and green is least vulnerable

- The Himalayan Forest Eco-region are the most vulnerable to climate change
- The coastal and Western Ghats regions (esp. the northern part of Western ghats are more vulnerable) and others are moderately vulnerable to climate change
- The north-east region is minimally projected to be impacted by climate change (as there are predictions of increase in rainfall)

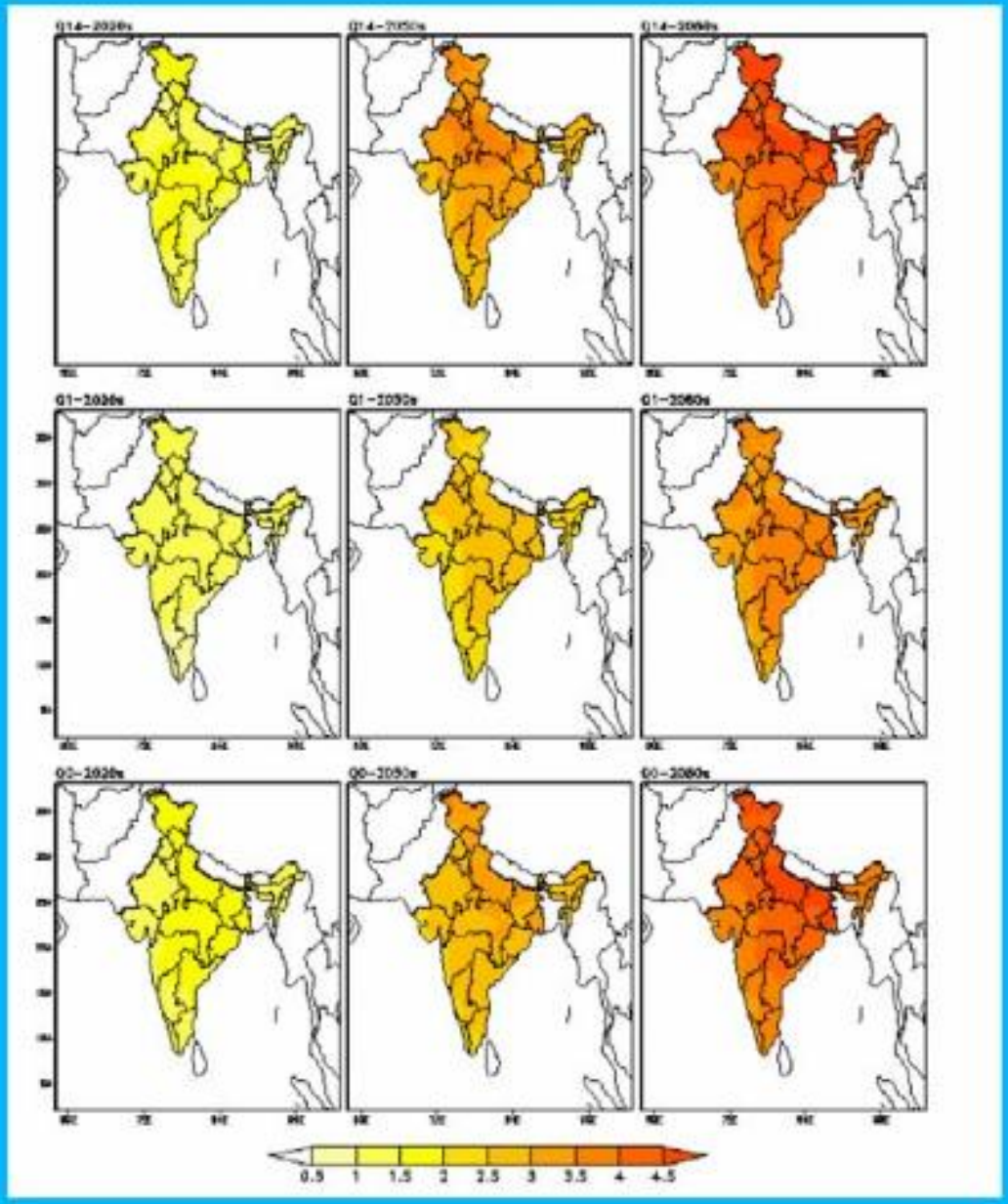


Figure 10: Projected future changes in mean annual surface air temperature (°C) in 2020s, 2050s and 2080s with respect to baseline (1961-1990)

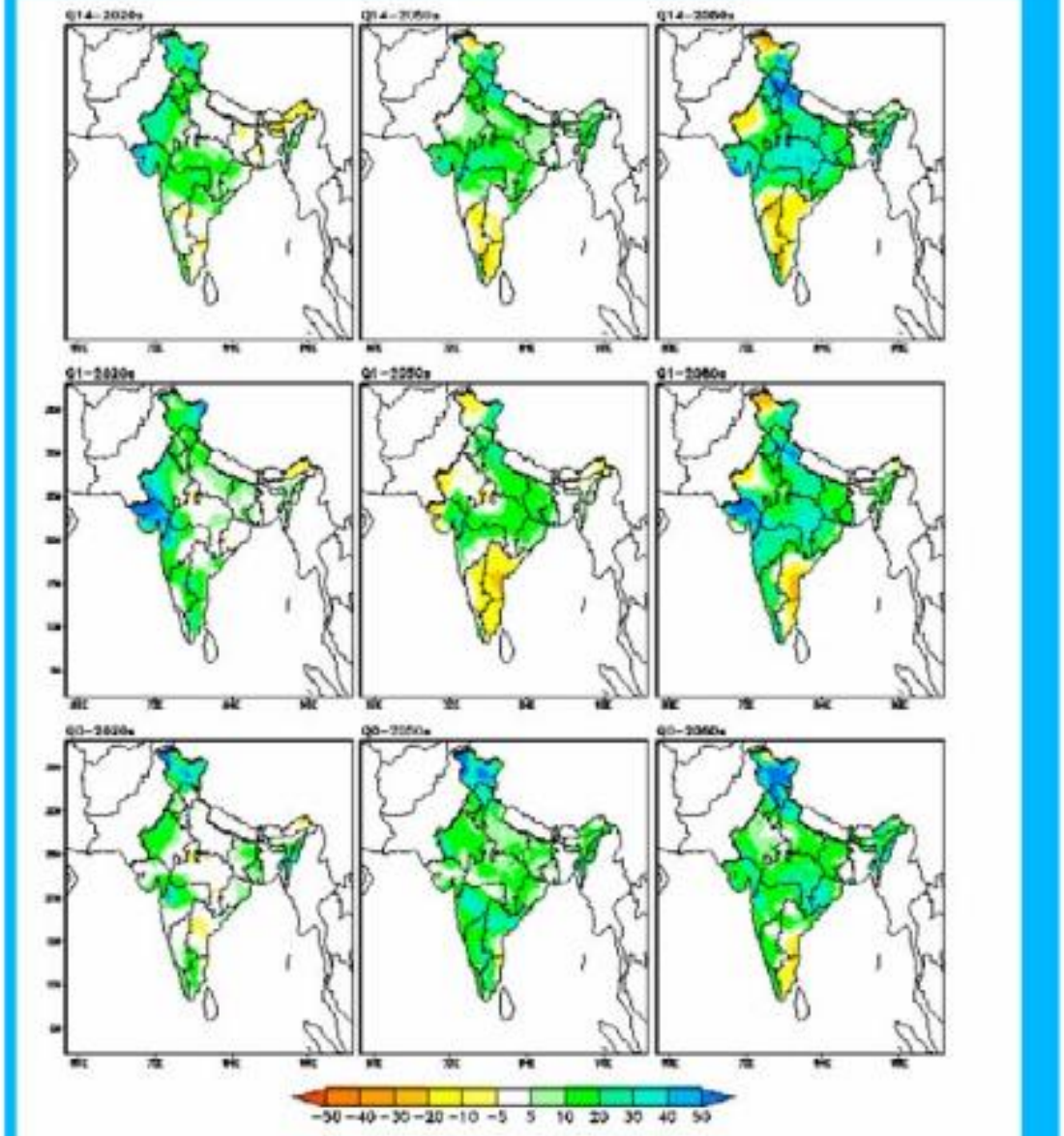
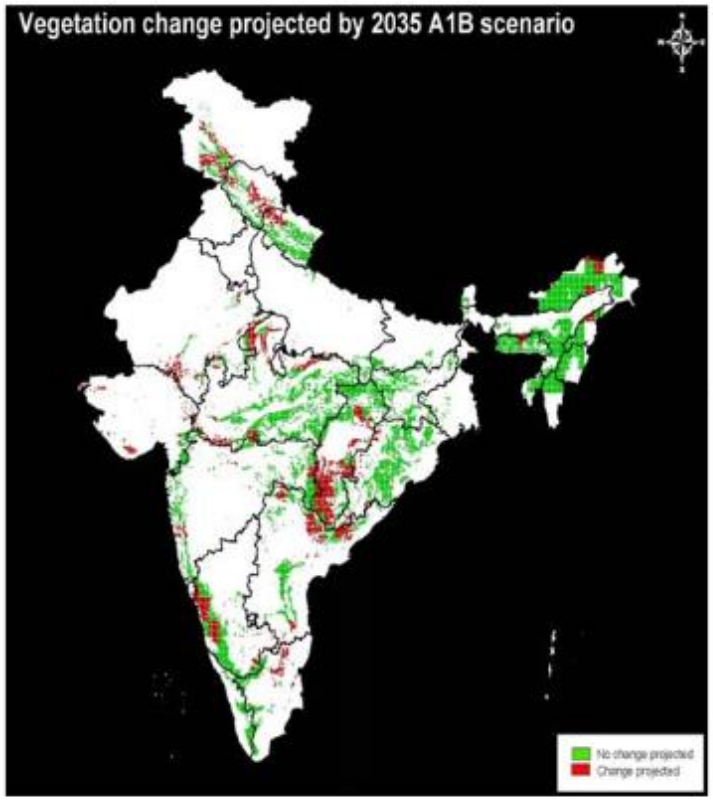
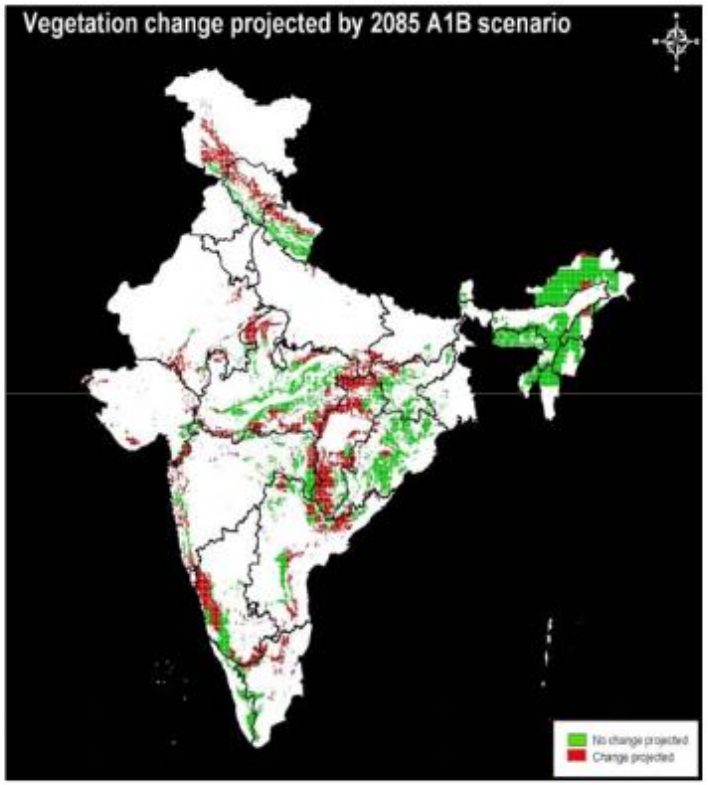


Figure 9: Projected future changes in mean monsoon precipitation (%) in 2020s, 2050s and 2080s with respect to the baseline period of 1961-1990

Projected Vegetation Change





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

Impact Studies

The Third Assessment Report of IPCC

- Forest ecosystems could be seriously impacted by future climate change. Even with global warming of 1-2°C
- Most ecosystems and landscapes will be impacted through changes in species composition, productivity and biodiversity
- Two studies in Himachal Pradesh & Western Ghats indicated moderate to large-scale shifts in vegetation types, with implications for forest dieback and biodiversity.

Likely impacts

- Increased incidence of drought & fire
- Migration of species towards higher latitudes & elevations
- Decrease in area under socio-economic important species like Deodar, Oak, Sal etc.
- Increasing spread of invasive species
- Flora & fauna falling out of synchrony
- Adverse impact on biodiversity
- Adverse impact on forest ecosystem services

- Mean value of NPP is estimated to be 835 g C/m2 per year under Current climate scenario
- NPP is projected to increase in all the forested grids mainly due to the CO2 fertilization effect on forest ecosystems
- Biodiversity is likely to be impacted under the projected climate scenarios due to the changes or shifts in forest or vegetation types (in 57 to 60% of forested grids), forest dieback during the transient phase, and different species responding differently to climate changes even when there is no change in forest type.
- Climate change will be an additional pressure and will exacerbate the declines in biodiversity resulting from socio-economic pressures.

Projection of Change in Forests

- 2085- 77% (A2) and 68% (B2) of the forested grids in India are likely to experience shift in forest types
- Shift towards wetter forest types in the northeastern region and drier forest types in the northwestern region in the absence of human influence
- Increasing atmospheric CO2 concentration and climate warming - doubling of net primary productivity under the A2 scenario and nearly 70% increase under the B2 scenario

- 77% of the grids under A2 and 68% under B2 scenario are likely to undergo vegetation change. This indicates that well over half of the area under forests in India is vulnerable to the projected climate change
- **International Union of Forest Research Organization** projected 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.

Table 1. Annual rainfall and temperature changes in the different forest types of India under B2 GHG scenario for the year 2085

Forest type	Number of grids	% area	Mean annual rainfall (mm)	Change in rainfall (mm)	Mean temperature (°C)	Change in temperature (°C)
Fir	290	0.82	730.1	221.6	9.5	3.0
Blue-Pine (Kail)	311	0.88	763.0	223.5	10.5	3.0
Chir-pine	791	2.25	1373.4	437.4	17.1	2.8
Mixed conifer	1071	3.04	930.1	375.9	9.3	3.0
Hardwoods Conifers mix	296	0.84	1560.7	585.6	13.1	2.8
Upland Hardwoods	881	2.50	1523.8	476.9	16.4	2.7
Teak	3364	9.56	1314.6	353.0	26.1	2.9
Sal	4251	12.08	1435.2	348.3	24.6	2.7
Bamboo Forest	567	1.61	2268.3	564.9	23.8	2.7
Mangrove	201	0.57	1734.3	280.8	26.6	2.5
Miscellaneous forest	22339	63.48	1679.8	374.5	23.0	2.7
Western Ghat evergreen forest	163	0.46	3111.3	368.7	25.4	2.4

Source: Forest types and area[12]

- Only about 6% of grids under the Tropical Xerophytic Shrubland -unchanged under the B2 scenario,
- 59% grids changing into Tropical Deciduous Forests/Woodlands
- 32% changing into Tropical Savanna.
- 8% Warm Mixed Forests change into Temperate Conifer Forests, 37% of the grids under Warm Mixed Forests are likely to change to Warm Mixed forests
- Existing Tropical Evergreen Forests are likely to remain so under theB2 scenario, increase due to shifts experienced by the Tropical Deciduous and Tropical Semi-deciduous forest types.

- Tropical Xerophytic Shrubland undergo large-scale reduction while Tropical Savanna and Evergreen Forests undergo expansion.
- The economically important forest types-*Tectona grandis, Shorearobusta, Bamboo, Upland Hardwoods and Pine- change.*
- *Pine,* Teak, Sal and Bamboo -over 75% grids - Change.
- Minimal or no change Western Ghats Evergreen, Semi-evergreen and Mangrove Forest types.

Table 3. Illustration of changes in forest types; number of grids under control scenario and % of grids under GHG scenario (B2) for dominant forest types

Forest Types	No. of grids in Control scenario	% of Grids under each forest type under the GHG scenario (B2)										
		TPXS	TPD/ WL	WM	TPSD	TPS	TPEG	TMC	TMSW	CC	ET/M	CLDMX
TPXS	14160	6	59	0	0	32	0	0	0	0	0	0
TPDWL	9389	0	54	0	1	8	35	0	0	0	0	0
WM	4753	0	16	58	7	0	9	8	0	0	0	0
TPSD	2790	0	1	0	7	0	91	0	0	0	0	0
TPS	1549	0	29	0	0	66	4	0	0	0	0	0
TPEG	962	0	0	0	0	0	100	0	0	0	0	0
TMC	274	0	8	37	6	0	41	5	0	0	0	0
TMSW	258	0	1	86	0	0	0	0	11	0	0	0
CC	234	0	0	94	0	0	0	0	2	2	0	0
ET/M	221	0	0	24	0	0	0	1	0	26	19	14
CLDMX	183	0	0	79	0	0	0	0	6	0	0	0

TPXS: Tropical xerophytic shrubland
TPD/WL: Tropical deciduous forest/woodland
WM: Warm mixed forest
TPSD : Tropical semi-deciduous forest
TPS: Tropical savanna
TPEG : Tropical evergreen forest
TMC: Temperate conifer forest
TMSW: Temperate sclerophyll woodland
CC: Cool conifer forest
ET/M: Evegreen taiga/montane forest
CLDMX: Cold mixed Forests

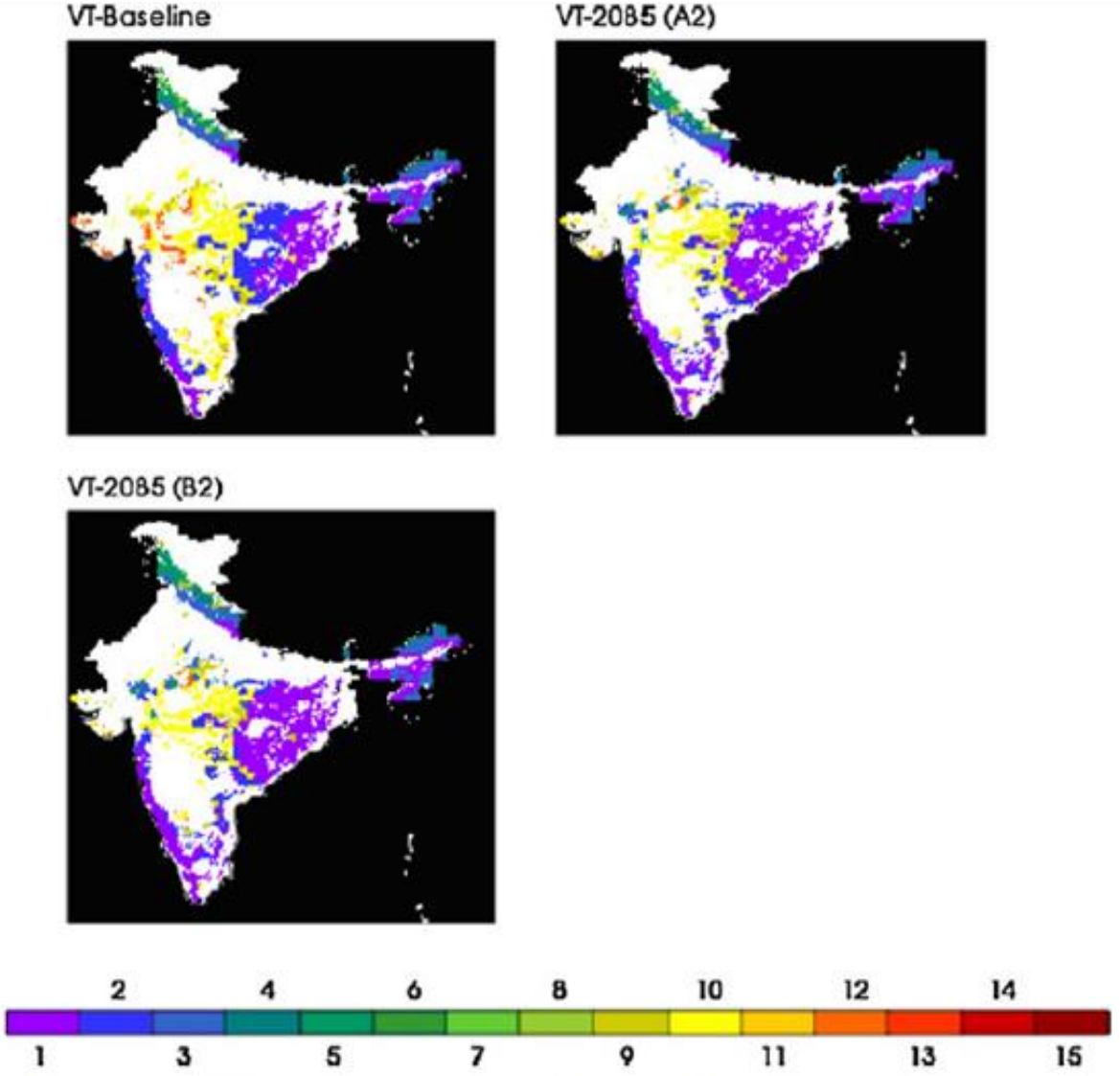


Fig. 11 Forest type distribution and extent simulated by IBIS for the baseline case and A2 and B2 scenarios. White areas represent non-forested grids. (VT—refers to Vegetation Types. The numbers refer to the following vegetation types 1: tropical evergreen forest / woodland, 2: tropical deciduous forest / woodland, 3. temperate evergreen broadleaf forest / woodland, 4: temperate evergreen conifer forest / woodland, 5: temperate deciduous forest / woodland, 6: boreal evergreen forest / woodland, 7: boreal deciduous forest / woodland, 8: mixed forest / woodland, 9: savanna, 10: grassland/ steppe, 11: dense shrubland, 12: open shrubland, 13: tundra, 14: desert, 15. polar desert / rock / ice)

Change in Net Primary Productivity

- Among the dominant vegetation types (Tropical Xerophytic Shrubland, Tropical Deciduous Forest, Warm Mixed Forest and Tropical Semi- deciduous Forest), the NPP increases by 1.35 to 1.57 times under the GHG scenarios (A2 and B2) over the Current scenario NPP.
- Tropical Evergreen Forest increases by 1.5 times
- The rate of increase on NPP was lower for Cool Conifer Forest, Cold Mixed Forest and Temperate Deciduous Forest.
- Generally the rate of increase is higher for warmer vegetation types.
- Vegetation carbon would increase by 290 GtC between 1860-2100 (compared to 600-630 GtC for the present day).
- NPP is projected to increase from 45-50 GtC per year in the 1990s to about 65 GtC/year by 2080s

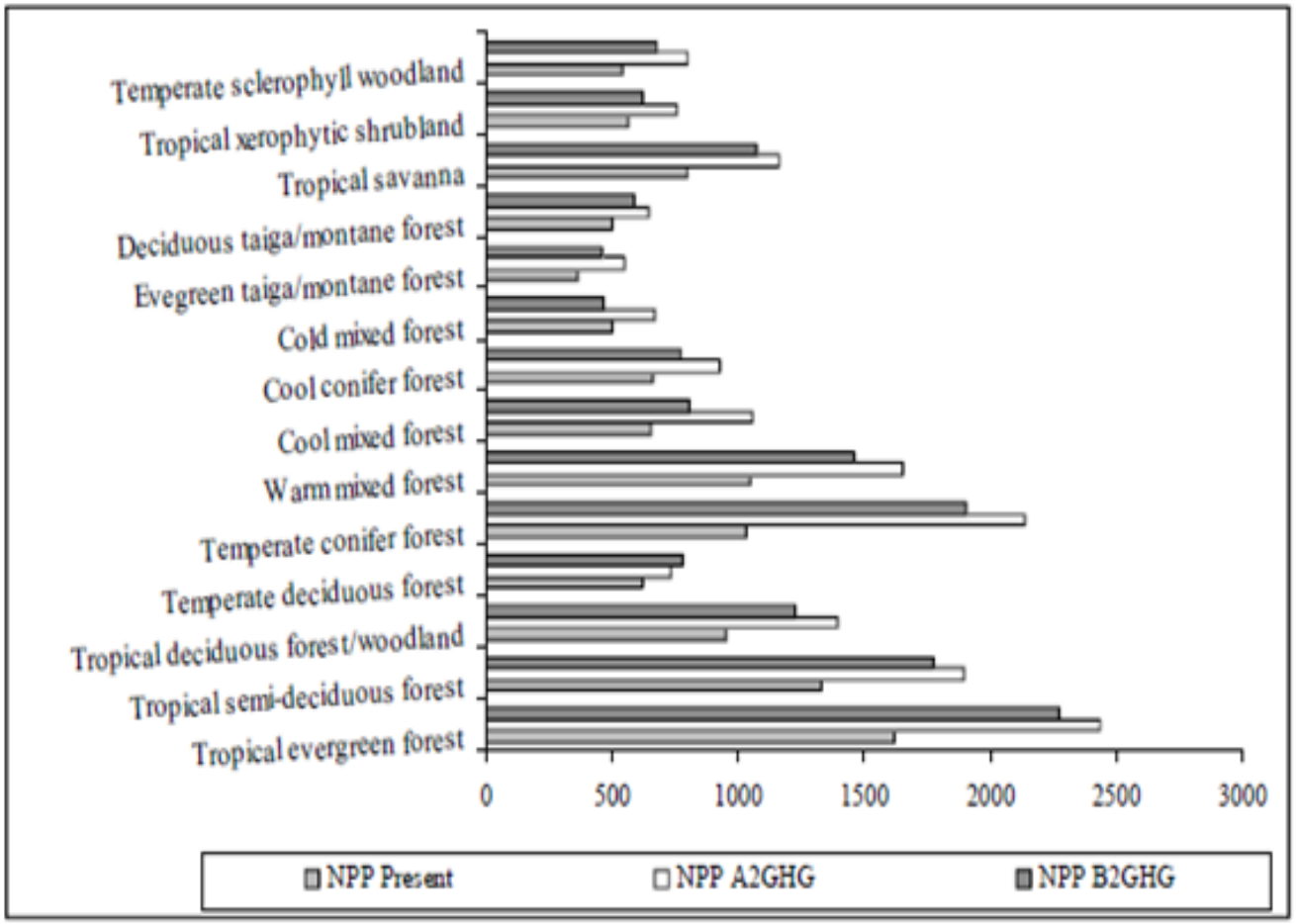


Figure 3. Climate impacts on NPP; % Forest biome-RCM grids subjected to change in NPP under GHG scenario over the current scenario under B2 Scenario

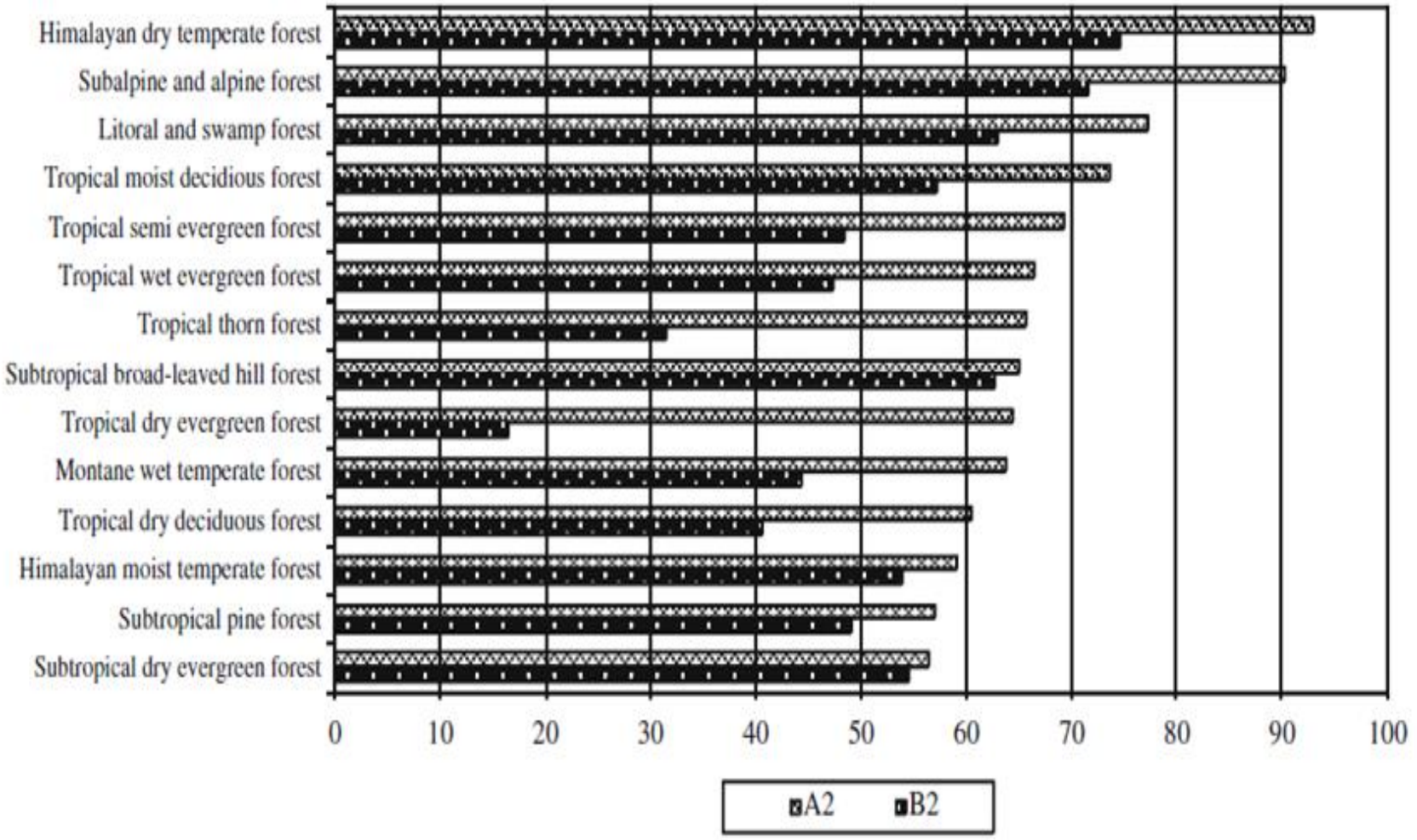


Fig. 15 Percentage change in NPP by 2085 for A2 and B2 scenarios compared to baseline (according to Champion and Seth 1968 classification)

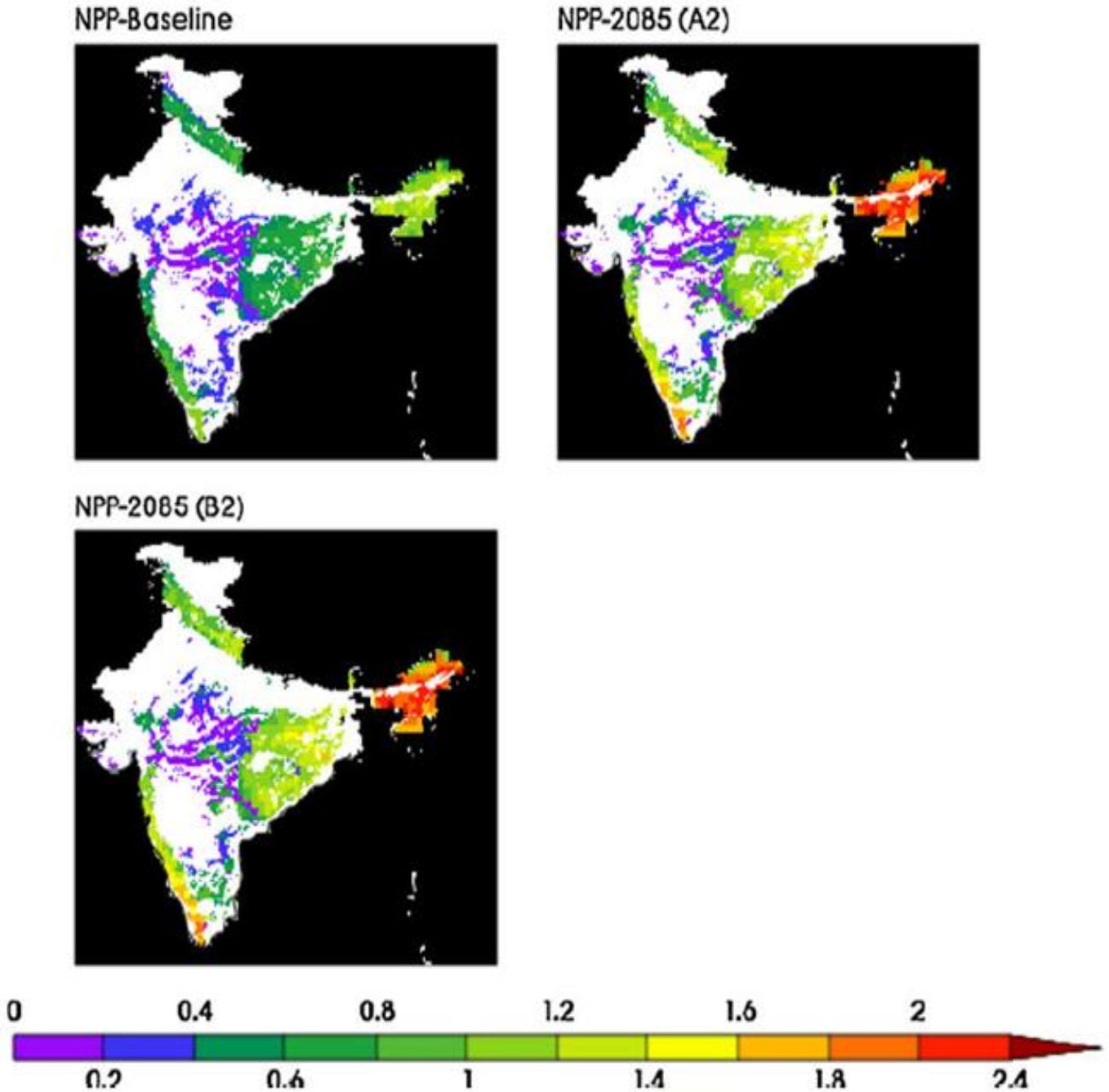


Fig. 13 NPP distribution (kgC/m^2) simulated by IBIS for the baseline case and A2 and B2 scenarios

References

- **Impact of Climate Change on Forests in India**

  -N. H. Ravindranath1, N.V. Joshi1, R. Sukumar1 and A. Saxena2

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- Impact of climate change on Indian forests: a dynamic vegetation modeling approach

  -Rajiv K. Chaturvedi & Ranjith Gopalakrishnan & Mathangi Jayaraman & Govindasamy Bala & N. V. Joshi & Raman Sukumar & N. H. Ravindranath

THANK YOU