Chapter 4
Forestry Policies and Practices to Promote Climate Change Adaptation in the Indian Western Himalayan States

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Abstract Indian Western Himalayas (IWH) represent one of the regions of the world where climate change is likely to be rapid and pose a serious threat to the rich biodiversity and ecosystem services. The IWH region is one of the mega-biodiversity centers where many initiatives have been taken to conserve its biodiversity. The region serves as the water catchment area for several rivers, providing water to the downstream states for agriculture and consumption and indirectly feeding and employing a significant portion of the country's population. Climate change brings with it new difficulties to undermine basic ecosystem resilience. The protection and sustainable management of ecosystems of the IWH, on the other hand, may provide a variety of socioecological advantages for long-term adaptation against both present and future climate change. Forests are essential for climate change mitigation efforts; however, they must adapt to climate change to maintain their own life as well as to provide support for the people who rely on them. Adaptation actions are performed to mitigate or minimize the detrimental effects of climate change by taking advantage of good possibilities and building resistance to the negative ones that arise. Forests' ability to adapt to climate change varies based on their geographical location and species. To deal with the problems of climate change, it is necessary to develop an adaptation framework that considers the roles of various sectors in forestry development and management. A framework may be created by combining the perspective of the community with the policies and plans of the government. This chapter illustrates the various existing forestry policies prevalent in the western Himalayan states aiming at climate change adaptation. The findings would be useful for policymakers to further integrate and seek possibilities of synergizing actions to develop a better adaptation framework for the region.

Keywords Adaptation · Forest management · Climate change · Ecosystem services · Biodiversity

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1 Introduction

There are just a few regions on Earth where climate change might be as fast as the Himalayan region. Climate change would impact biodiversity, ecological services, and human well-being in this region much significantly (Chaturvedi et al., 2011). The Indian Western Himalaya (IWH) is a mega-biodiversity center and has been selected for several biodiversity conservation projects (IIRS, 2002; NMSHE, 2010) and forestry-based measures to combat the impacts of climate change. The region is the water catchment area for many rivers that provide water to the downstream states for irrigation and personal as well as industrial consumption (MoEF, 2010). The main consequences seen in the area include floods in snow-fed rivers, glacier retreat, water unpredictability, and soil, forest, and grassland degradation (Pachauri et al., 2014). The region is highly vulnerable to climate change and is facing the increasing incidences of forest fires, drying springs, loss of biodiversity, forest land diversion, increasing human-wildlife conflict, and illegal trade of forest products (Kumar et al., 2021a).

Adaptation is defined as "adjustment in natural or anthropogenic systems in response to definite or expected climatic stimuli or their effects, which moderate destruction or exploit advantageous opportunities" (IPCC, 2007). Adaptation measures are taken to nullify or reduce the adverse impact of climate change by exploiting beneficial opportunities and developing immunity against the negative ones. Modulation for sustenance is carried out keeping in view the present risk and anticipating further diversification in climatic conditions. To counteract the rising human population density, equilibrating processes are pulled from a shrinking region of global natural habitats. Earth ecosystems supply multiple resources that are shared by numerous countries and have an impact that goes beyond the borders of a particular nation. To prevent a "tragedy of the commons," when a common resource is overexploited, governments and other stakeholders must resist this temptation to exploit (Galvani et al., 2016).

Adaptation for *natural forests* involves "conservation, protection, and restoration strategies," whereas options for adapting to climate change in *managed forests* include "sustainable forest management, adjusting tree species compositions to build resilience, and coping with the increased risks of pests and diseases and fire" (IPCC, 2022). Restoring natural forests and improving the sustainability of managed forests, in general, will make carbon stocks and sinks more resilient (Haq et al., 2021). Policies must be framed in a way to work together with local communities and indigenous peoples to ensure forest adaptation. Mountain ecosystems have already hit their hard adaptation limitations as a result of rising global temperature. With the rise of global warming by 1.5 °C, mountain ecosystems are anticipated to lose their ability to adapt (IPCC, 2022).

In the absence of adequate adaptation measures, climate change in addition to the nonclimatic drivers will harm the world's forests (McCarthy, 2001; Smit & Wandel, 2006). Government policies for various developmental plans and measures to combat the adverse impacts of climate change demand consideration of factors

such as improving awareness among the community about climate risks and its mitigation options and initiatives to lower the cost of adaptations, improving the farm-household assets and alternative livelihood, and improving access to services (Ali & Erenstein, 2017; Dhyani et al., 2021; Kalra & Kumar, 2018; Kumar et al., 2021b). There is a need to work together with the government and the local community to make sure that policies are properly implemented, especially those that could minimize the impacts of climate change with an assurance that people adapt to it (Kumar et al., 2019b). A study in the Indian Himalayas on community forestry by Gupta and Koontz (2019) demonstrated how the government can work together with nongovernment partners (NGOs) for the effective implementation of policies of forest conservation. The government could provide technical and financial assistance, while on the other, NGOs could drive the communities to those resources and compensate for each other's weaknesses. This will make it easier for communities to participate in forest governance.

The adaptation of forests to climate change varies to various degrees depending on their region and type. To cope with the challenges of climate change, the requirement is to design a framework for adaptation considering the role of different sectors. The framework can be developed by synergizing community perception and various governmental policies and programs (Kumar et al., 2021b). This chapter aims to describe the numerous climate change adaptation programs that have been launched and implemented in the IWH region, with a focus on forestry. The major findings of the policy document on the State Action Plan on Climate Change (SAPCC) for the respective IWH states have been summarized with a focus on presenting information that directly relates to the actions oriented for the forestry sector that would assist in climate change adaptation. In the end, other major policies that could be integrated for climate change adaptation measures involving forestry-related initiatives have been summarized. The chapter will assist planners to have a ready source of information on existing policies for the IWH region. At the same time, this will supplement information for people who intend to formulate any policies advocating forestry-based adaptation measures to combat the impacts of climate change.

2 Biophysical and Socioeconomic Characteristics of the Study Region

The IWH is a complex geographical region with varying altitudes and orientations. This makes the region complex and would witness the effects of climate change in a different manner, which will have spatial variations (Padma, 2014). The long-term trends in temperatures across the northwestern Himalayas imply a significant increase in air temperature, with winter warming happening at a faster rate (Bhutiyani et al., 2007). The region may witness minimum temperature rise by 1–4.5 °C and maximum temperatures rise by 0.5–2.5 °C (MoEF, 2010). The varying

Table 4.1 Biophysical and socio-economic characteristics of the Indian Western Himalayas (IWH)

Parameter	J & K (includes Ladakh)	Himachal Pradesh	Uttarakhand	IWH
General				
Geographical area (km^2)	2,22,236	55,673	53,483	3,31,392
Population (million)[a]	12.50	6.86	10.12	29.58
Number of districts[a]	22	12	13	47
Number of villages[a]	4939	20,690	16,793	42,422
Land use pattern[a] *(hectare)*				
Permanent pastures and other grazing land	33.07	1,507,522	192,077	16,99,632.07
Fallow land (current and other than current)	111.94	78,791	143,619	2,22,521.94
Land under misc. tree crop and groves not included in net area sown	1096.62	64,905	387,817	4,53,818.62
Net area sown	7,57,450.70	543,365	700,171	20,00,987.70
Climatic parameters				
Annual temperature (min.-max., °C)	Subzero to 40	−15 to 43	−2.4 to 41.5	−2.4 to 43
Average rainfall (mm)	600–800	1800	1550	600–1800

Source: ISFR (2011) and [a]Census of India (2011)

altitude of the region produces unique pattern of vegetation that varies spatially having subtropical, conifer, grasslands, and alpine meadows. The changing climate has started influeincing the flora and fauna of the region with a shifting of their habitat (Singh et al., 2020). The region is represented by two union territories of Jammu and Kashmir (J & K) and Ladakh and two states, namely, Himachal Pradesh (HP) and Uttarakhand (UK). *Before the creation of union territories in 2019, the J & K and Ladakh represented the common state of Jammu and Kashmir. Therefore, most of the statistics and policies reviewed and presented in this chapter are common for the combined UT of present J & K and Ladakh mentioned as* J & K *or* JK. The biophysical and socioeconomic characteristics of the region are highlighted in Table 4.1.

The IWH can be divided into three zones based on geology and topography, namely, higher Himalayas or Himadri, lesser Himalayas or Himachal, and outer Himalayas or Shiwaliks. The climate of the IWH is quite temperate – often referred to as the extratropical mountain climate. The altitude of the IWH region varies from 97 to 7144 m above the mean sea level (Fig. 4.1). There is also a strong influence of the continental effects as reflected in the large annual and diurnal range of temperature (IIRS, 2002). In the valleys of Kashmir, Kullu, and Dehradun, predominantly alluvial soil is found, whereas brown soils are found in the hills.

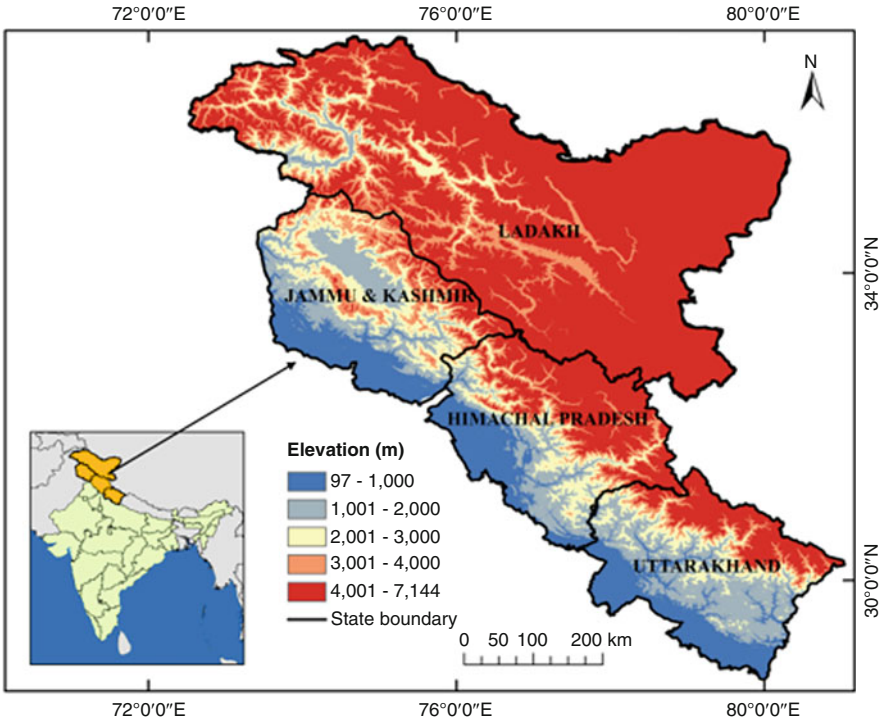

Fig. 4.1 Elevation ranges in the Indian Western Himalayan region

3 Adaptation Initiatives in the IWH Region

Adaptation initiatives aim to address the risks and effects of climate change. Well-framed adaptation strategies will drastically reduce the stress of climate change. Sustainable forest management (SFM) practices are a dynamic and growing concept that aims to continue and improve the socioecological and economic importance of forests, for the benefit of present and coming generations (Dhyani et al., 2021; Kumar et al., 2021b). However, well-planned target-oriented adaptation initiatives will ensure better preparedness to withstand the ill effects of climate change and extreme events. For climate-sensitive areas such as IWH, climate change adaptation should be an integral part of good governance and development. The forest ecosystem needs the longest response time to adapt to climate change, which varies for forest types and regions (Kumar et al., 2018; Rawat et al., 2020).

Adaptation plans are needed to deal with the effects of climate change and the harm it causes. It should be ensured to incorporate adaptation strategies in developmental and mitigation projects. Challenges of connecting adaptation research to policymaking include insufficient information about existing indigenous knowledge,

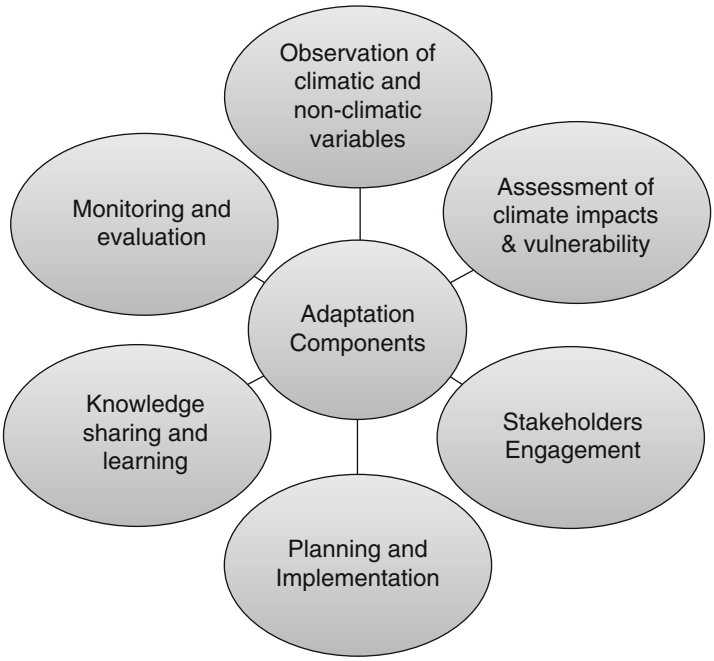

Fig. 4.2 Adaptation components linked with forest ecosystem and climate change

poor participation of local communities in decision-making processes, lack of awareness and education among the forest-dependent communities, poor forecasting and early warning systems, etc. (Murthy et al., 2011). Various adaptation components that can be linked with the forest ecosystems are shown in Fig. 4.2.

3.1 Integration of Adaptation Initiatives in the State Action Plan on Climate Change

The Indian Government launched the National Action Plan on Climate Change (NAPCC) on June 30, 2008, which focuses on understanding climate change-related issues. All the states and union territories were directed by the Central Government to prepare and adopt the State Action Plan on Climate Change (SAPCC) in 2009. The design and guidance for preparations were provided by the Union Ministry of Environment, Forest and Climate Change. States act as focal points for respective geographic areas. The development of the State Action Plan has been a significant effort in delineating regional climate vulnerability, exploring future projections, and formulating actionable strategies. The SAPCC adheres to the objectives and strategies of the national action plan on climate change to safeguard the poor and vulnerable sections of the societies through sustainable development strategy,

sensitivity to climate change, enhancing ecological sustainability and mitigating greenhouse gas emissions, using appropriate technologies for adaptation and mitigation of greenhouse gas emissions, and embracing international cooperation.

The SAPCC is in accordance with eight national missions forming the core of the National Action Plan, which are "National Solar Mission, National Mission for Enhanced Energy Efficiency, National Water Mission, National Mission on Sustainable Habitat, National Mission for Sustaining the Himalayan Ecosystem, National Mission for a Green India, National Mission for Sustainable Agriculture, and National Mission on Strategic Knowledge for Climate Change" (https://dst.gov.in/climate-change-programme). SAPCC outlines the policies for addressing climate change–related issues. The action plan is based on state sectoral policies and themes. The strategy focuses on impact mitigation and adaptation methods to preserve the states' unique environment. Table 4.2 depicts the objectives, thrust areas, and initiation of the state action plan in the IWH.

3.1.1 Major Proposed Actions Under Jammu and Kashmir State Action Plan on Climate Change

The key priorities proposed under the J & K SAPCC include (i) implementation of J & K State Forest Policy 2011 for forest conservation and improvement of degraded forests; (ii) quantify per capita annual fuelwood availability and consumption; (iii) generation of weather and climate data and to ensure its easy access; (iv) preparation of an eco-restoration plan; (v) to study the phenology of important tree species by monitoring flowering and fruiting pattern; (vi) to conduct study to estimate the soil organic matter (SOC) pool under different forest covers, serving as a benchmark for future investigations of changes in SOC pool; (vii) to study the feasibility for developing mechanism under the UNFCCC to REDD+; (viii) collect data on climate effects, development of framework for the assessment of impacts, decision support tools, and successful adaption methods; (ix) to track carbon influxes/outflows from diverse forest types/trees and their contribution to carbon sequestration; (x) capacity building through the specific training modules and the dissemination of information via regional workshops; and (xi) annually convene educational seminar, forum, workshop and to disseminate knowledge-based products. Suggested actions focused on forestry in combating climate change is summarized in Table 4.3.

3.1.2 Major Proposed Actions Under Himachal Pradesh State Action Plan on Climate Change

The key priorities proposed under the HP SAPCC include: (i) Sanjhi Van Yojna Scheme by the involvement of grass root level institutions such as Gram Panchayats, Mahila Mandals, Yuvak Mandals, Village Forest Development Societies (VFDSs), Community-Based Organizations (CBOs) and NGOs in sustainable management of forest resources; (ii) Jan-Jan Sanjeevani Van Abhiyan initiated in 2008, which ensured the distribution of more than 1.50 million of medicinal plants to the rural

Table 4.2 Initiation, objectives, and thrust areas of Jammu and Kashmir (includes Ladakh), Himachal Pradesh, and Uttarakhand State Action Plan on Climate Change

State	Enacted date	Objectives	Thrust areas
Jammu and Kashmir (includes Ladakh)	August 9, 2011	Construct adaptation and mitigation strategies toward stabilization of emissions, increase ecosystem resilience, diversify the dependency on natural resources	Management of forests Soil and water conservation Estimation of soil carbon Stabilizing emissions Enhancing ecosystem resilience Eco-restoration plan Improving the livelihood of forest-based communities Wetland development Forest protection
Himachal Pradesh	November 14, 2011	Improving the societal awareness and preparedness Increasing the robustness of infrastructural design and long-term investments Increasing the flexibility of vulnerable managed systems	Reducing forest degradation Decreasing livestock pressure on forests Encouraging community participation through JFM Promoting alternatives to fuelwood Monitoring forest encroachment Regeneration of crops Networking the fragmented protected area Improving the production of natural resources and income of rural households Sustainable development Agrarian economy Water sources for drinking and irrigation Sustainability of hydro economy
Uttarakhand	January 19, 2011	Creating framework with respect to response strategies and sustainable development	Conservation of natural resources Enhancing forest area Conservation of soil and water Capacity building Management of fire Encouraging sustainable development Securing livelihood Buffering ecosystem services

Table 4.3 Actions and programs for the forestry sector focusing adaptation measures in Jammu and Kashmir (JK & Ladakh)

S. no.	Major thrust area	Proposed activities
1.	Implementation of J & K State Forest Policy 2011	A comprehensive plan for the conservation of existing forests Restoring degraded forests
2.	Capacity building and awareness for all levels of stakeholders	Improving the skills of forest department personnel to recognize the impacts of climate change on forests Training includes legal aspects of forest and environmental issues
3.	Gene bank development for climate-adaptable species	Identification of vulnerable species and species that have wider adaptability over larger geographical area to ensure their genetic conservation
4.	Eco-restoration through afforestation and climate oriented eco-restoration plan	Preparation of an eco-restoration plan for climate change mitigation Influence the State's carbon budget
6.	Flora and Fauna vulnerability study	To undertake a study to see the changes in floral and faunal composition Understand and manage horticulture, which is a major source of livelihood and revenue.
7.	Studies of carbon influxes/out fluxes of various forest types/trees and their role in carbon sequestration	Carbon stock estimation and assessment of sequestration potential for prominent forest species To ensure improved estimates based on micro-meteorological and inventory methods
8.	Study on per capita firewood consumption and alternative livelihood	Quantify per capita annual fuelwood availability and consumption Livelihood improvement of forest-dependent communities Encouraging communities for forest conservation
9.	Study on SOC of forest area	To conduct studies for the estimation of the SOC pool
10.	Climate impact study in undisturbed/protected forest areas	To conduct climate impact studies in undisturbed and protected forests to study the possible climate change effects without interference from other disturbances, including anthropogenic causes of forest degradation
11.	Climate change impacts on undisturbed forest areas like national parks	To study the impact of climate change on national parks such as the efficiency of carbon sequestration, changes in feeding patterns, reproduction and migration pattern, impact of tourism, etc.

(continued)

Table 4.3 (continued)

S. no.	Major thrust area	Proposed activities
12.	E-green portal with geo-reference	To conduct a field survey with modern instruments /standalone GPS Developing an E-green portal to provide thematic information
13.	Nursery development for climate-adaptable species	To conduct programs for the production of high-quality climate-adaptable seedlings Establishment of clonal nurseries and root trainers The seedlings to be utilized by the forest department, while surplus seedlings to be sold to the public
14.	REDD+ feasibility study for carbon sequestration	To study the feasibility for developing mechanism under the UNFCCC to REDD+
15.	Studies on sustained water availability	To stop decline in groundwater level, conserve surface water run-off, ensure soil conservation, reduce soil erosion, water conservation measures through new and improved technologies To study the rate of glacier melting and its impact in associated areas To address critical issues of water sustainability influenced by increasing population and climate change

Source: http://moef.gov.in/wp-content/uploads/2017/08/Jammu-Kashmir.pdf

and urban households through 5000 distribution points; (iii) in 2013, Department of Environment, Science and Technology (DEST) developed an Environment Master Plan that established baseline data for the identification of ecological sensitive zones and the critical issues that impact them; (iv) BioCarbon sub project as an additional component of the mid Himalayan watershed program with an objective to engage small and marginal farmers in tree planting initiatives to add value to ongoing watershed operations; (v) Herbal gardens for the cultivation of medicinal plants; (vi) Community-led Assessment, Awareness, Advocacy and Action Plan for Environment Protection, and carbon neutrality to evolve Himachal as a sustainable and climate resilient state; (vii) Organic Himachal initiative to take into account a complete range of organic farming such as vision, mission strategy about policy, awareness, technology and support to the farmers, quality assurance of the state produces and to develop policies to make Himachal an organic compost rich state; (viii) As a part of national bamboo mission, planting bamboo species in areas of Kangra, Nahan, Mandi, Hamirpur along with marketing of bamboo.

The government of Himachal Pradesh took upon the Environment Master Plan (EMP) to ensure a long-term outlook on attaining sustainable development. It was established to safeguard the long-term viability of natural resources and cultural legacy. The EMP has been envisaged as a guide tool to provide strategies regarding environmental issues. The EMP of the state for the forestry sector has been summarized in Table 4.4.

Table 4.4 Actions and programs for the forestry sector focusing adaptation measures in Himachal Pradesh

S. no.	Major thrust area	Proposed actions
1.	Forest degradation	Encouraging community participation through joint Forest Management (JFM) Implementation of state plans for the reforestation and regeneration of forests Promoting natural regeneration, afforestation and plantation Eco-development programs Encouraging wild fruit trees plantation Development of watersheds in order to conserve soil and water Monitoring of project programs like JFM, eco-development program, watershed Strengthening of catchment area treatment plan
2.	Increase in anthropogenic pressure	Increase in forest cover per capita through JFM in wastelands or degraded lands. Developing plans for managing fallow lands and wastelands Developing livelihood programs and educating the migratory Gujjar grazers to adopt agro-economic activities Suggest alternatives of fuel wood, such as utilizing renewable resources and also promoting smokeless *chulha* by providing subsidy for better kitchen hygiene
3.	Increasing livestock pressure on forests	Plantation of community orchards and fodder crops Identification of common land for pasture Upgrading breeds and reducing nonproductive livestock Developing stall feeding and growing grasses to reduce grazing pressure on forests
4.	Timber distribution rights	Update and amendment in the regulation of timber distribution Assessment of timber needs and monitoring of felling of marked trees Promoting agroforestry to meet the need for timber. Strict actions against defaulters
5.	Forest encroachment	Demarcation of the forest land with pillars Periodic monitoring of the area Imposing strict laws like the Forest act, town and planning act
6.	Unsustainable harvesting of the forest produce	Monitoring at the time of harvest of forest produce Preserving and documenting the germplasm of aromatic as well as medicinal plants Use of biotechnology for propagation Enforcing regulatory measures Conducting programs and surveys for spreading awareness among people

(continued)

Table 4.4 (continued)

S. no.	Major thrust area	Proposed actions
7.	Ban on green felling leading to inhibited natural regeneration	To remove the blockage and to induce regeneration of crops, thinning can be carried out Setting up permanent plots for long-term monitoring to understand the forest ecology
8.	Not taking into account diversification of species	Encouraging mixed plantations of willow, oak, fir, bamboo, wild fruit species Planting deodar and Kail along with Chil and fir/spruce Use of pine needles for making of briquettes so as to reduce pressure on fuelwood Monitoring afforestation, plantation, and nursery works
9.	Natural hazards and forest fire	Cooperation of villagers to protect forests from fire as well as help the forest department Zila Parishad, Gram Panchayat to motivate community involvement in firefighting, protection, and afforestation
10.	Forest diversion for non-forestry purposes	Alternative solutions like bio-engineering under catchment area treatment plans A strict application of policy guidelines
11.	Fragmented protected area network	Reviewing the existing protected area network in respect to bio-geographic zones and forest types at regular intervals
12.	Crop damage by wild animals	Introducing crop insurance schemes Vegetative barriers Providing compensation Creating buffer zones
13.	Stress on wildlife population	Monitoring and reporting illicit cases to the concerned authority Carrying out awareness programs to educate the people about the ill effects about poaching
14.	Alien and invasive species leading to loss of native vegetation	Monitoring and eradication of alien and exotic species from forest area Preparation of suitable work plans to identify infested areas with invasive species Establishing a techno-economic feasibility assessment and encouraging the use of lantana bush products

Source: http://www.indiaenvironmentportal.org.in/files/file/ExecutiveSummaryEnvironmentMasterPlan.pdf

3.1.3 Major Proposed Actions Under Uttarakhand State Action Plan on Climate Change

The key priorities proposed under the UK SAPCC include (i) improving silvicultural techniques with climate change considerations; (ii) research on removal of invasive species and ex situ conservation; (iii) surveying the population dynamics and

movement of wildlife; (iv) estimation of total carbon stock and annual increment for Uttarakhand; (v) assessing biodiversity of various ecosystems; (vi) documenting the traditional knowledge related to biodiversity; (vi) evaluating the impact of climate change on high-altitude wetlands, alpine meadows, and moraines; (vii) forest fire management and prioritizing corridors; (viii) enhancing the area under forests and trees and also increasing the quality and density of degraded forests by natural regeneration in moderately dense forests, planting climate-resilient species, and managing interference in scrub forests; (ix) recognizing vulnerable areas with expert assistance; and (x) revamping local institutions. Suggested actions focused on forestry in combating climate change is summarized in Table 4.5.

4 Developmental Policies, Programs, and Practices for Adaptation focusing Forestry in the IWH Region

Forests contribute to the global atmospheric gas concentration by influencing the carbon cycle by the capturing and releasing of carbon through its various processes. Realising the importance of forests for the global climate change scenario, the UN adopted Agenda 21, which is a nonbinding, voluntarily implemented action plan with a focus on climate change, conservation of biodiversity, and forests.

The carbon potential of India's forests changes due to various promotional initiatives for enhancing the forest cover as well as various pressures, which leads to forest degradation and deforestation (Savita et al., 2018a) leading to loss of biomass and thus carbon. India's various acts and legislations are focusing on the management and conservation of its forests such as the Forest Conservation Act (1980) to limit arbitrary forest land diversion and regulate land-use changes in existing forest areas, thereby reducing deforestation. National Forest Policy, 1988, was the backbone of major policies adopted in India, which prioritized forests for maintaining environmental steadiness and ecological equilibrium, motivating participatory forest management, and the stimulus to farm forestry. It provided the first accusation on forest produce to local communities. Important initiatives by various agencies of India for forest conservation and management are presented in Table 4.6.

Among all initiatives, the JFM initiated in 1990 by the Ministry of Environment and Forests (MoEF) serves in a better way that involves the local community in the management actions for the management of forest resources. It ensures the involvement of local communities for the protection and management of forests. Among the most important aspects of this program are increasing the capacity at various levels, the establishment of institutions, and sharing of benefits between the state and the communities (Ravindranath & Sudha, 2004). The local communities and government manage the forests resources and share the cost and benefits equally. The 2000 guidelines on JFM by the MoEF, Government of India, strengthened the original mission, included women's involvement, and brought structural challenges all under one roof. The JFM is envisioned as a powerful instrument for preventing additional

Table 4.5 Actions and programs of the forestry sector focusing adaptation measures in Uttarakhand

S. no.	Major thrust area	Proposed activities
1.	Increasing the existing area under forests and improving open and degraded forests	Management interventions in scrub forests (1 km^2/year) Site-specific activities for the maintenance of existing forests and new plantation Plantation of climate-resilient species that would benefit local communities Implementation of assisted natural regeneration activities
2.	Enhancing natural resources and livelihood options of the vulnerable sections	Providing livelihood options to local communities Rangeland management Agroforestry/farm forestry Mapping of important rangelands using remote sensing approach Alternate livelihood options such as NTFPS collection, biomass briquetting, eco-tourism, establishment of nurseries, and cultivation of medicinal plants Establishment of quality planting material production centers Conservation of bugyals (2500 ha per annum) Protection and management initiative toward regulated grazing
3.	Soil and water conservation	Close watch on glaciers Maintenance of soil moisture regime Raising large-scale rainwater harvesting structures for water conservation Vegetation approach to soil and moisture conservation Introduction of three-tier forest plantations
4.	Fire management	Management of fuel load Maintenance of fire lines to control forest fire Ensure alternate energy sources Making firefighting quick response team equipped with advance firefighting tools and early warning systems Regular monitoring of fire threats Controlled and cool burning
5.	Research and capacity building	Monitoring and evaluation of carbon stock Monitoring the forest carbon flux Annual increment of total carbon stock in Uttarakhand
6.	Short-term research projects	Climate change–related impacts and adaptation strategies Ecological and physiological studies in important forest types Adapt and develop vegetation models for climate change impact studies

Source: https://moef.gov.in/wp-content/uploads/2017/08/Uttarakhand-SAPCC.pdf

Table 4.6 Developmental policies, programs, and practices in the forestry sector relevant to climate change adaptation

Social- and climate-related initiatives	Objectives	Date of initiation
Joint Forest Management (JFM)	To safeguard forest with collaboration between the forest department and local communities	1990
Compensatory Afforestation Fund Management & Planning Authority (CAMPA)	Utilizing fund for afforestation in efficient manner	2002
National Afforestation Programme (NAP)	Rehabilitation of degraded forest through JFM & Forest Development Agency	2000
National Afforestation & Eco-development Board	Promote afforestation, ecological, restoration and eco-development activities	1992
Pradhan Mantri Krishi Sinchayee Yojana (PMKSY-WC)	More crop per drop-extending irrigation coverage and improving water use efficiency	2015
Reducing Emissions from Deforestation and Forest Degradation (REDD+)	Reducing gas emissions, halting reversing forest loss	2015/2017
Forest PLUS	Promote scientific and technical collaboration in the forestry sector and accelerate India's transition to a low carbon economy	2010
Green India Mission (GIM)	Protecting, restoring, and enhancing forest cover	2008
National Rural Employment Guarantee Act (NREGA)	Guarantees employment to unemployed people	2006
Rainfed Area Development	Enhancing agriculture productivity and minimizing the risk associated with climatic variabilities	2011–2012
Namami Ganga	Abatement of pollution, conservation and rejuvenation of national river Ganga	2014

forest degradation. The logic behind JFM is to put a collective responsibility on local communities and forest staff to protect the forest meticulously. The JFM can fulfil local subsistence requirements of fuelwood, fodder, NTFPs, small timber, etc., while avoiding degradation of forests that give local, national, and international environmental advantages.

Forests are an important source of varieties of ecological services, to compensate for these losses; many afforestation programs have been carried out in the IWH region to divert nonforest land into forest land. Since afforestation doesn't start giving services overnight, there is still the loss of goods and services that would have been provided by the forests that had been laid down for completing the demands of industries and other developmental activities. To compensate for the loss in the interim, the net present value (NPV) of the diverted forest is calculated for 50 years, and the same is recovered from the agency that is diverting the forest land. To manage and utilize the amount collected sum, Compensatory Afforestation Fund

Management and Planning Authority (CAMPA) was formed. The State CAMPA is meant to speed up efforts related to forest preservation, wildlife management, sector infrastructure development, and other related activities. These efforts accelerate the annual rate of plantations. The plantations raised are mainly of eucalyptus, teak, acacia, poplar, casuarinas, pine, bamboo, and other miscellaneous species.

The National Afforestation and Eco-development Board (NAEB) works in the direction of promoting afforestation and eco-development activities across the country, with special attention toward degraded forest areas, protected areas like national parks and sanctuaries, as well as ecologically fragile areas like IWH. Different schemes operated by NAEB include afforestation and eco-development schemes, fodder and fuelwood schemes, NTFPs, and medicinal plant-related schemes. To assist the state forest departments in the effective implementation of technologies and to provide other aids, the board has seven regional centers. These centers evaluate NAEB's program in the field and organize training programs and workshops. They also act as a platform for exchanging ideas and experiences among different regions. The regional centers' work programs are meant to promote the sustainability of different afforestation and forest management programs. These programs cover training for forest-based microenterprises, studies on improved silvicultural practices, and interdepartmental linkage workshops at the district level for synergy of various forest conservation schemes of the government. Based on these programs, it is expected that forest-based microenterprises could scale up as a channel of promoting sustainable livelihoods for forest fringe communities. According to the principle of eliciting and cultivating people's involvement, the National Association for Forest Healing (NAEB) offers suitable financial support to organizations working in the cause of forest healing.

The World Bank takes into account various issues like climate change, finance, trade, agriculture, education, and food security intending to reduce poverty and share prosperity in developing countries. Various World Bank-assisted programs being enacted in the IWH region include (i) Sustainable Land and Ecosystem Management (SLEM), (ii) Uttarakhand Decentralized Watershed Development Project, (iii) Himachal Pradesh Horticulture Development Program, and (iv) Mid-Himalayan Watershed Program implemented in the HP.

The SLEM is a bilateral program initiated by the Government of India and the Global Environmental Facility (GEF) under the Country Partnership Programme. The SLEM program aimed at maintaining the capacity of the ecosystem to deliver goods and services, while keeping climate change in mind, promoting sustainable land management, and conserving and developing natural resources. The program has been initiated in the states of Madhya Pradesh, Nagaland, Rajasthan, and Uttarakhand. In the IWH region, the program has been carried out in Uttarakhand only. The main objective of the SLEM project in Uttarakhand was to rehabilitate and preserve the ecosystem's functions and biodiversity, also increasing income and improving livelihood. It aims to achieve zero net land degradation, that is, aiming at

practices that lead to a balance of carbon and also mitigating climate change by sequestering carbon dioxide.

India's national REDD-plus (Reducing Emissions from Deforestation and Forest Degradation) strategy focuses on increasing and improving the country's forest and tree cover, hence increasing the quantity of forest ecosystem benefits that come to local communities. Development and implementation of REDD+ at the national level require close coordination and strong linkages between all stakeholders of the forest sector, which will need to be guided by the MoEF. The Ministry of Environment, Forests, and Climate Change has formed a REDD+ Cell, which is tasked with the coordination and guidance of REDD+-related activities on a national and subnational level, as well as at regional, state, and local levels. The REDD+ Cell would provide guidance on the concept, planning, financing, execution, supervision, and assessment of REDD+ programs in various jurisdictions. The Cell works closely with the Climate Change Division and the Forest Policy Division within MoEF for analytical application, implementation, and reporting of REDD-plus actions and also actively facilitates nationwide coordination.

Almost 2,00,000 villages are classified as forest fringe villages in India, which represents the dependence of communities on forest resources (FRI, 2017). This provides enough scope and opportunity in the Indian communities for integrating REDD+ initiative activities (Kumar et al., 2020b). However, this suggests evolving methodologies and strategies for a procedural framework addressing REDD+ objectives for ensuring people's participation and sharing of the benefits accruing from REDD+ incentives.

Forest PLUS is a joint program between India and the United States for developing different methods for forest management and also for the sustainable use of forests in India. Forest PLUS program stimulates India's conversion to a low carbon economy and also formulates India to implement REDD+ successfully. Forest Plus is associated with the Green India Mission, REDD+, and National Action Plan on Climate Change and also works with MoEF, local governments, NGOs, and State Forest Department. It is a USAID (United States Agency for International Development)-funded project focusing on the reduction of greenhouse gas emissions from the forested landscapes of India. The main objectives of the program are (i) sustainable use of forests, (ii) low carbon economy, (iii) development of systems for monitoring forest carbon, (iv) improving the land use planning and reducing deforestation, (v) conducting inventories for greenhouse gases, and (vi) cost-effective management of forests. Forest PLUS brings together Indian and American experts to strengthen, enhance, and improve various technologies, techniques, and strategies of forest management in meeting the challenges of managing and maintaining forests for ecological sustainability, carbon storage, species diversity, and livelihood opportunities. It associates with the local communities and the Indian forestry institutions in the areas of Karnataka, Madhya Pradesh, Sikkim, and Himachal Pradesh (Kumar et al., 2021b).

The Green India Mission (2010) was considered an inclusive participatory mission for greening India through the decentralized governance structures mandating community engagement in traditional afforestation programs. The mission

ensures participation of grass-root groups in the preparation, decision-making, execution, and evaluation phases. The key objectives of the Mission are to "increase forest/tree cover on 5 m ha of forest/non-forest lands and improved quality of forest cover on another 5 m ha (a total of 10 m ha); improve ecosystem services including biodiversity, hydrological services, and carbon sequestration as a result of treatment of 10 m ha; increase forest-based livelihood income for 3 million forest-dependent households; enhance annual CO_2 sequestration of 50–60 million tons by the year 2020." Green India Mission directly or indirectly is associated with the climate change adaptation strategy.

Rainfed area development has a very crucial role to play in the Indian economy as well as agriculture (Savita et al., 2018a). Rainfed regions are the regions where crop production is dependent on rainfall. India grades one among rainfed countries but least in rainfed yields (<1 t/ha). Sixty-four percent of the country's sown area is rainfed (https://nraa.gov.in/). These areas are occupied by the majority of India's rural poor and marginal farmers experiencing difficulties and risks in biophysical and socioeconomic conditions. Poverty, water scarcity, low yields, malnutrition, and lack of infrastructure are few difficulties faced by the communities depending on these areas. Rainfed areas are susceptible to changing climate due to their poor potential to cope with severe water and weather stress. According to Central Research Institute for Dryland Agriculture, rainfed areas are those that receive an annual rainfall of 750–800 mm and has <30% of irrigated land. The National Rainfed Authority (NRAA) is now serving as an advisory body for policy formulation and monitoring schemes to resolve agricultural challenges across the vast rainfed system of the nation, whereas the National Mission for Sustainable agriculture aims at promoting sustainable agriculture.

River Ganga originates from the IWH, which directly and indirectly is correlated with the forest ecology of the Himalayan region. Forest-dependent communities (FDC) are dependent on the Ganga river for several livelihood activities. Namami Gange Programme is a "flagship program" of government of India, initiated in 2014 with a budget outlay of 20,000 crore to abate pollution, and to ensure conservation and rejuvenation of National River Ganga within a time frame of 5 years for medium-term activities and 10 years of long-term activities (https://nmcg.nic.in/). The vision for Ganga Rejuvenation is to ensure "Aviral Dhara," that is, continuous flow, and "Nirmal Dhara," that is, unpolluted flow. One of the envisaged major activities for Ganga rejuvenation is forestry intervention to enhance the productivity and diversity of forests in headwater areas all along the river (Savita et al., 2018b). Multi-tier plantations including trees, shrubs, grasses, medicinal plants, etc. can be raised. Deterioration in the form of biodiversity decline, degradation of land and water resources, pollution, etc. can be controlled by developing a natural corridor along the river. A holistic approach through amalgamating various schemes and programs like National Afforestation Programme, Green India Mission, NREGA, etc. can help attain the objectives effectively.

Being in the lap of the great Indian Western Himalayas, enriched with large forest cover and glacier source of various rivers, states like Jammu and Kashmir, Himachal Pradesh, and Uttarakhand are vulnerable to flash floods, forest fire, and cloud bursts

along with other natural disasters. Disasters are disturbances to a community's existence and livelihood caused by hazard effects, resulting in loss of life and environmental damage beyond its capability to manage alone. Disaster management provides aid to cope with calamity and act as a core component of sustainable development. Disaster management plans are aimed to build resilience in the socioeconomic resources and functions to reduce vulnerability and mitigate risks. With a vision of building a safer and disaster-resilient India, the Disaster Management Act, 2005, was framed. Under this act, various national and state-level institutions were established for reducing risks, preventing losses, and preparing, responding, and recovering through hazardous conditions.

The regions of the Indian Western Himalayas are rich in diversity, where the valleys receive a good amount of rainfall and also have rich soils. But the temperate region of Ladakh faces climatic stress against agricultural growth. These regions also face soil erosion, thus affecting the soil fertility as well as the crop produce. Wheat, maize, and rice are the major crops produce, whereas apples, plums, and apricots are the major fruits produced in these regions. Many schemes and programs have been implemented aiming toward sustainable agriculture. Few schemes have been discussed in this section. The National Mission for Sustainable Agriculture (NMSA) obtains its acceptance from Sustainable Agricultural Mission, which is one of the eight missions in the National Action Plan on Climate Change. The mission (NMSA) is designed to make Indian agriculture resilient to climate change. NMSA has been prepared to improve agricultural productivity, especially in rainfed areas with an emphasis on the efficiency of water use, resource conservation, and soil health management. The components of NMSA are rainfed area development, soil health management, climate change, and sustainable agriculture. NMSA emphasizes sustainable agriculture through a course of adaptation measures such as refined seed crops, the efficiency of water use, improved livestock and fish cultures, pest and nutrient management, livelihood diversification, markets and agricultural insurance, and access to credit support and information.

5 Mainstreaming Adaptation in Forest Planning and Management

Adaptation addresses the risks and effects of climate change. Well-framed adaptation strategies will drastically reduce the stress of climate change. Strategies such as REDD+, Sustainable Forest Management (SFM), and conservation and enhancement of carbon stocks already exist. The SFM strives to maintain and increase the economic, social, and environmental value of all forest types for current and future generations. Effective adaptation measures will improve preparation for climate-related changes, especially severe occurrences. Climate change adaptation should be part of effective governance and development in climate-sensitive places like IWH. The forest ecosystem needs the longest response time to adapt to climate change.

Adaptation practices vary for different regions and forest types. A few adaptation strategies including the suggestion of Murthy et al. (2011) are indicated below.

- Promoting in situ and ex situ conservation
- Planned afforestation and adopting silvicultural practices
- Reducing forest fragmentation in order to facilitate species migration
- Promoting natural regeneration and mixed-species forestry
- Linking and expanding protected areas to promote the migration of species
- Developing sustainable forest management practices and reducing deforestation
- Promoting and developing temperature-tolerant and pest-resistant species
- Alternate techniques to fuelwood to decrease pressure on forests, promoting the use of bio-briquettes
- Building capacity to create and execute climate change adaption methods
- Promoting conservation of biodiversity-rich forests
- Increasing the amount of land already covered by forests while also enhancing the quality and density of degraded forests
- Promoting agroforestry as a means of increasing biophysical and socioeconomic resilience
- Establishing quality planting material production centers
- Conservation of soil and water by rejuvenating traditional *chals*
- Fire management involving quick response teams, regular monitoring of fire threats using satellite imagery and information technology
- Education and training programs for forest-dependent communities
- Infrastructure development in the rural areas
- Involving the active participation of local communities in forest conservation schemes
- Promoting regeneration of native species and short-rotation species
- Monitoring and management of forest areas
- Promoting bio-energy plantations and adaptive co-management between the forest authorities and local communities

There is a definite need for effective adaptation strategies involving the above-suggested measures to cope with climate change and damages caused due to climate change.

6 Conclusion and Way Forward

Climate change is posing new challenges and has the potential scope to severely impact various ecosystems. The unprecedented speed and type of change threaten the fundamental ecosystem resilience (IPCC, 2007). On the other hand, the conservation and sustainable management of ecosystems can facilitate multiple socioecological benefits and support long-term approaches to climate change adaptation against both current climate change and future climate change (Kumar et al., 2019a; Schmitt et al., 2009).

Forests are critical for mitigative measures for climate change (Kumar et al., 2020a). However, forests also need to adopt the changes in the climate to sustain their existence as well as to support the dependent communities. Broadly, the linkage between forests and climate adaptation is twofold: firstly, forests are important due to their role in delivering ecosystem services; and secondly, reducing the vulnerability of the society to the ill effects of climate change. Hence, there is a need to develop and implement policies that have two components of "forests for adaptation" and "adaptation for forests."

The varying levels of uncertainty, limited information, and risk, against the impacts of climate change, are posing problems for the conservation of the forests. Moreover, it is difficult to extrapolate the appropriate knowledge about the forest response to adapt against the disturbances in the forests due to climate change (Füssel, 2007; Giupponi & Biscaro, 2015; Hinkel, 2011; Kumar et al., 2020a; Smit & Wandel, 2006). The segregated evaluation of forest ecosystems across the world through models shows that there will be impacts on the forests from cell level to ecosystem levels such as species composition, the productivity of the forests, and phenology, resulting in changing the deliverables of the forests to the communities. These changes in forests will be detrimental to the forest itself and communities too, specifically for the adaptation aspect. Therefore, by neutralizing and nullifying these impacts and conserving the system, it becomes capable to modulate itself according to the prevailing conditions. For this, an appropriate mechanism has to be devised and implemented. Implementing the earlier approaches of forest management may be unreceptive and can be ecologically inappropriate and socially undesirable. Therefore, modified approaches inclusive of various resources and all stakeholders' involvement with cross-scale and cross-sectoral linkages will be essential to capture the dreadful impacts leading to better adapt the changes (Locatelli et al., 2008).

In the above context, under the changing climate, there is a need to implement measures for reducing the climate change impacts on the forests. The mechanism for supporting the adaptability of the forests revolves around strengthening the intrinsic characteristics of the forest ecosystem as well as supporting extrinsically by various means leading to the growth and development of the forest ecosystem. The internal components of the forests include the topography and edaphic factors besides the micro-climatic condition and hydrology, the important components for enriching the food preparation, and assimilation of the plants. Biodiversity is the most important component for measuring the strength of adaptability of the forest ecosystem. Balancing these factors through any means ranging from engineering works to anthropogenic activities may facilitate forest ecosystem growth.

The external support may broadly include those mechanisms that are either directly or indirectly supporting the growth of the forest ecosystem during the changes occurring in the climate. These factors include governance to silvicultural management and facilitating the communities with resources that support climate-smart farming so that a balance can be made between the social and ecological systems. The other includes the role of the community and support from the industrial sector as well as the inflow of research inputs and right information. A framework addressing the major prominent issues of the IWH region should be in place to support the policy need for a better adaptation plan.

References

Ali, A., & Erenstein, O. (2017). Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. *Climate Risk Management, 16*, 183–194.

Bhutiyani, M. R., Kale, V. S., & Pawar, N. J. (2007). Long-term trends in maximum, minimum and mean annual air temperatures across the Northwestern Himalaya during the twentieth century. *Climatic Change, 85*, 159–177.

Census of India. (2011). *Office of the Registrar general & Census Commisioner, India*. Ministry of Home Affairs, Government of India, New Delhi. Office of the Registrar General & Census Commisioner, India. Ministry of Home Affairs, Government of India, New Delhi.

Chaturvedi, R. K., Gopalakrishnan, R., Jayaraman, M., Bala, G., Joshi, N. V., Sukumar, R., & Ravindranath, N. H. (2011). Impact of climate change on Indian forests: A dynamic vegetation modeling approach. *Mitigation and Adaptation Strategies for Global Change, 16*, 119–142.

Dhyani, S., Murthy, I. K., Kadaverugu, R., Dasgupta, R., Kumar, M., & Gadpayle, K. A. (2021). Agroforestry to achieve global climate adaptation and mitigation targets: Are South Asian countries sufficiently prepared? *Forests, 12*, 303.

FRI. (2017). *Forest resource dependence and ecological assessment of forest fringes in rainfed districts of India*. Forest Research Institute. Ministry of Environment, Forest and Climate Change, Government of India, Dehradun.

Füssel, H.-M. (2007). Vulnerability: A generally applicable conceptual framework for climate change research. *Global Environmental Change, 17*, 155–167.

Galvani, A. P., Bauch, C. T., Anand, M., Singer, B. H., & Levin, S. A. (2016). Human–environment interactions in population and ecosystem health. *Proceedings of the National Academy of Sciences, 113*, 14502–14506.

Giupponi, C., & Biscaro, C. (2015). Vulnerabilities – Bibliometric analysis and literature review of evolving concepts. *Environmental Research Letters, 10*, 123002.

Gupta, D., & Koontz, T. M. (2019). Working together? Synergies in government and NGO roles for community forestry in the Indian Himalayas. *World Development, 114*, 326–340.

Haq, S. M., Calixto, E. S., & Kumar, M. (2021). Assessing biodiversity and productivity over a small-scale gradient in the protected forests of Indian Western Himalayas. *Journal of Sustainable Forestry, 40*, 675–694.

Hinkel, J. (2011). "Indicators of vulnerability and adaptive capacity": Towards a clarification of the science–policy interface. *Global Environmental Change, 21*, 198–208.

IIRS. (2002). *Biodiversity characterisation at landscape level in Western Himalayas, India using satellite remote sensing and geographic information system*. Indian Institute of Remote Sensing, Dehradun.

IPCC. (2007). *The physical science basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Intergovernmental Panel on Climate Change (IPCC), Climate change 2007*. Cambridge University Press.

IPCC. (2022). *Climate change 2022. Impacts, adaptation and vulnerability. Summary for policymakers. Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental panel on Climate Change*. Cambridge University Press.

ISFR. (2011). *India State of Forest Report*. Forest Survey of India, Ministry of Environment, Forest and Climate Change, Government of India, Dehradun.

Kalra, N., & Kumar, M. (2018). Simulating the impact of climate change and its variability on agriculture. In S. Sheraz Mahdi (Ed.), *Climate change and agriculture in India: Impact and adaptation* (pp. 21–28). Springer.

Kumar, M., Rawat, S. P. S., Singh, H., Ravindranath, N. H., & Kalra, N. (2018). Dynamic forest vegetation models for predicting impacts of climate change on forests: An Indian perspective. *Indian Journal of Forestry, 41*, 1–12.

Kumar, M., Savita, Singh, H., Pandey, R., Singh, M. P., Ravindranath, N. H., & Kalra, N. (2019a). Assessing vulnerability of forest ecosystem in the Indian Western Himalayan region using trends of net primary productivity. *Biodiversity and Conservation, 28*, 2163–2182.

Kumar, M., Singh, M. P., Singh, H., Dhakate, P. M., & Ravindranath, N. H. (2019b). Forest working plan for the sustainable management of forest and biodiversity in India. *Journal of Sustainable Forestry*, 1–22.

Kumar, M., Kalra, N., & Ravindranath, N. H. (2020a). Assessing the response of forests to environmental variables using a dynamic global vegetation model: An Indian perspective. *Current Science, 118*, 700–701.

Kumar, M., Savita, & Kushwaha, S. P. S. (2020b). Managing the forest fringes of India: A national perspective for meeting the sustainable development goals. In: *Sustainability perspectives: Science, policy and practice, strategies for sustainability* (p. 331). Springer.

Kumar, M., Kalra, N., Singh, H., Sharma, S., Rawat, P. S., Singh, R. K., Gupta, A. K., Kumar, P., & Ravindranath, N. H. (2021a). Indicator-based vulnerability assessment of forest ecosystem in the Indian Western Himalayas: An analytical hierarchy process integrated approach. *Ecological Indicators, 125*, 107568.

Kumar, M., Phukon, S. N., & Singh, H. (2021b). The role of communities in sustainable land and forest management. In: *Forest resources resilience and conflicts* (pp. 305–318). Elsevier.

Locatelli, B., Kanninen, M., Brockhaus, M., Colfer, C. P., Murdiyarso, D., & Santoso, H., (2008). *Facing an uncertain future: How forests and people can adapt to climate change*.

McCarthy, J. J. (2001). *Climate change 2001: Impacts, adaptation, and vulnerability: Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

MoEF. (2010). *INCCA: Indian Network for Climate Change Assessment*. Climate change and India: A 4x4 assessment.

Murthy, I., Tiwari, R., & Ravindranath, N. H. (2011). Climate change and forests in India: Adaptation opportunities and challenges. *Mitigation and Adaptation Strategies for Global Change, 16*, 161–175.

NMSHE. (2010). *National Mission for Sustaining the Himalayan Ecosystem under National Action Plan on Climate Change*.

Pachauri, R. K., Meyer, L., Van Ypersele, J. P., Brinkman, S., Van Kesteren, L., Leprince-Ringuet, N., & Van Boxmeer, F. (2014). *Climate change 2014 synthesis report the Core Writing Team technical support unit for the synthesis report. Russ. Fed. Hoesung Lee (Republic Korea) Scott. B. Power NH Ravindranath*. Available online https//www. ipcc. ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover. pdf. Accessed 28 Jan 2020.

Padma, T. V. (2014). Himalayan plants seek cooler climes: Race is on to record mountain biodiversity before it is lost. *Nature, 512*, 359–360.

Ravindranath, N. H., & Sudha, P. (2004). *Joint forest management in India: Spread, performance and impact*. Universities Press.

Rawat, A. S., Kalra, N., Singh, H., & Kumar, M. (2020). Application of vegetation models in India for understanding the forest ecosystem processes. *Indian Forester, 146*, 99–100.

Savita, Kumar, M., & Kushwaha, S. P. S. (2018a). Forest resource dependence and ecological assessment of forest fringes in rainfed districts of India. *Indian Forester, 144*, 211–220.

Savita, Mathur, P. K., Sharma, L. K., & Kumar, M. (2018b). Forestry interventions for Ganga rejuvenation: A geospatial analysis for prioritising sites. *Indian Forester, 144*, 1127–1135.

Schmitt, C. B., Burgess, N. D., Coad, L., Belokurov, A., Besançon, C., Boisrobert, L., Campbell, A., Fish, L., Gliddon, D., & Humphries, K. (2009). Global analysis of the protection status of the world's forests. *Biological Conservation, 142*, 2122–2130.

Singh, H., Kumar, N., Kumar, M., & Singh, R. (2020). Modelling habitat suitability of western tragopan (Tragopan melanocephalus) a range-restricted vulnerable bird species of the Himalayan region, in response to climate change. *Climate Risk Management, 29*, 100241.

Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change, 16*, 282–292.