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Article

Climate change adaptation policies and institutional arrangement: Agriculture and fishery sector in India

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Abstract: India's agriculture and fishing sectors confront significant challenges due to climate change because of its distinctive geographical location and predominantly agrarian economy, highlighting the urgent need for institutional frameworks and effective adaptation strategies. This study delves into the current state of institutional structures and policies aimed at climate change adaptation within these key sectors in India. Through an exhaustive analysis of literature, official reports, and policy documents, the research evaluates the policies and interventions implemented to mitigate the impacts of climate change on agriculture and fisheries. Several policies are in place to facilitate the planning, establishment, and implementation of adaptation programs at the national and regional scales in the country. However, given India's broad geographical size and varied socio-cultural settings, the adaptation requirements of diverse sectors and susceptible populations are still not sufficiently recognized and addressed. Key areas under scrutiny include crop diversification, water management techniques, technological advancements, and community-based adaptation approaches. Furthermore, the study evaluates the effectiveness of existing institutional arrangements, including governmental bodies, academic institutions, and community organizations, in fostering climate resilience across different domains. By synthesizing insights from diverse sources, this research aims to offer valuable perspectives on the institutional dynamics and policy landscape shaping climate change adaptation efforts in India's agriculture and fisheries sectors to build resilience and sustainability. This research paper highlights some of the evolving as well as existing adaptation requirements and suggests how new research, policy, and practice engagements could meet these requirements.

Keywords: agricultural economy; climate change; adaptation policies; Himalaya; India

1. Introduction

India is among the largest countries in the world, both in terms of land area and population. The Indian Ocean lies to the south, while the snow-capped Himalayan hills to the north are its boundaries. The western part of this vast plain is the Thar Desert and the Arabian Sea, and the Bay of Bengal is in the east, which leads to experiencing a wide range of climatic conditions and varied biodiversity. The nation is also exposed to a variety of exciting meteorological events because of this extraordinary layout, including cyclones, droughts, and floods, which have destroyed infrastructure, put

lives in danger, and slowed down social and economic progress. It is projected that these risks will become more pronounced as climate change exacerbates sea level rise, intense weather, glacier retreat, and snowmelt.

Moreover, India is becoming gradually more vulnerable to climate fluctuation due to its fast-increasing population, poverty, and the need to meet the demands of a growing population on resources. Despite India's present ranking as the world's fifth-largest economy by nominal GDP but third by purchasing power parity (PPP) [1], the advantageous effects of economic growth have not been adequately acknowledged. Millions of Indians persist in poverty, have limited opportunities for basic resources like energy, water, and fertile land, and are dependent on livelihood systems that are susceptible to climate change, like fishing, farming, and livestock production, etc. The government of India has been attempting to address such a risk by launching numerous climate change adaptation strategies and programs that encompass a variety of stakeholder groups, from community-based organizations to national governments.

Although it has made substantial improvements in the past, Indian agriculture is today confronted with numerous challenges. Climate change impacts have been more pronounced in the agriculture sector in the recent past. Agriculture and fishery sectors around the globe are facing major challenges due to climate change, especially in developing countries with people who are highly reliant on their food security and livelihoods. Climate change has resulted in frequent and capricious extreme events, including droughts, floods, cyclones, landslides, typhoons, and sea level rise, that adversely impact Indian agriculture. A constant state of readiness is required to resist the effects of global warming, from the Himalayas to the coastal nations of South Asia.

The livelihoods and food security of the 36 million fisher folk worldwide, as well as the roughly 1500 million consumers who obtain more than 20% of their animal protein from fish, are increasingly under threat from global warming [2–4]. Despite mounting evidence of climate variability and change affecting aquatic ecosystems, fisherfolk livelihoods remain a neglected area in climate adaptation policy despite their significant impacts [5]. This study appraises the strategies, programs, and projects associated with climate change adaptation in India. Based on a comprehensive review of secondary data sources and interviews with key informants, it attempts to present a concise and explicit summary of adaptation strategies nationwide.

2. Materials and methods

2.1. Overview of research results on policies and institutional arrangements to adapt to climate change for the agriculture and fisheries sector

Human response and adaptation issues have only recently been considered in the debate on climate change [6] and the current agenda for climate change research does not give much attention to adaptation issues [7]. Many publications in this field prominently feature the word "adaptation" in their titles, but not in their contents [8,9]. This results in a grave mismatch between what is known about climate change, its effects, and how to deal with concerns locally and what is known globally [7]. Events, i.e., floods, droughts, ice storms, and hurricanes, demonstrate the limits to our ability

to adapt to existing climatic variations. Every society faces extreme events, and their economies and societies change as their climatic environment fluctuates [10].

Considering the growing concern about climate change impacts and the necessity to formulate a robust approach to address vulnerability rising from concrete and anticipated impacts, India published the National Action Plan on Climate Change (NAPCC) in June 2008. This NAPCC is both a response and an acknowledgment from India to the scientific appraisals of the IPCC AR4, which posits climate change as a global concern with potentially serious consequences [11,12]. Despite acknowledging that climate change poses a menace to India's speedy economic growth, the report says the issue is not of India's making and that the country must collaborate with the international community to cope with it collectively and cooperatively. A national adaptation strategy is first required, and secondly, the country must take advantage of the opportunity to achieve greater ecological sustainability as it develops [13].

Against this backdrop, in 2011, the Indian Council of Agricultural Research (ICAR) launched the 'National Innovations in Climate-Resilient Agriculture' (NICRA) network under the Ministry of Agriculture and Farmers Welfare. The NICRA intended to develop crop varieties resistant to climatic stresses, such as floods, droughts, inundations, frosts, and heat waves. Research is being conducted by 41 institutes of ICAR under the Strategic Research Component in several subject areas, such as the development of various stress-resistant crop genotypes, the measurement of greenhouse gas emissions from farmland and developing technologies to reduce them, the development of climate-resilient horticulture, heat-tolerant livestock, and adaptation and mitigation to climate change in poultry and small ruminants.

Several pathways exist through which climate change can affect fisheries. Changing surface water temperature, precipitation, or oceanographic variables, for instance, wave action, sea level rise, and wind velocity, can affect marine and freshwater ecosystems and fish populations in significant ecological and biological ways [2,14–18], directly impacting the livelihoods of people in these ecosystems. Fishing operations and land-based infrastructure can also be disrupted by extreme weather events, and fluctuations in fishery production can impact livelihood strategies and outcomes [2,19,20]. The chemistry of seawater has changed over the past two centuries as a result of rising oceanic CO_2 uptake led by rising atmospheric carbon dioxide (CO_2) concentrations [21].

The National Action Plan on Climate Change (NAPCC) of India has been in place for almost a decade. In 2010, the central government requested that state governments develop SAPCC since they have state jurisdiction over various aspects of the NAPCC, specifically adaptive actions. It was also intended to create coherence in the responses to climate change among states [22]. Several critical reviews [12,23–25] have indicated that regional plans at both the national and state levels exhibit unevenness and a delay in strategizing, establishing institutions, and implementing them. As part of the NAPCC, eight national missions were designed to implement action plans covering energy, habitats, water, and agriculture. Other missions are anticipated to focus on coastal zones, health, and waste management. As critical studies have outlined, the Action Plans and Missions do not adequately address institutional issues, specifically the necessity for appropriate institutional design, and the requirement for cross-agency and cross-scale collaborations [26].

India is a diverse and wide-ranging country with multiple social, economic, and political facets, which can prove challenging to develop an action plan, but the present paper argues that if the NAPCC is to become a personified document used by government agencies, non-government organizations, and researchers, it must be addressed for serious flaws, loopholes, and gaps to be addressed. This paper focuses on institutional problems, particularly how the action plans and missions at local, regional, and national scales fail to incorporate cross-scale and horizontal links. In part, the excess focus on mitigation is indicative of this neglect in critical appraisals of the NAPCC and National Missions afore adaptive strategies that address climate risks. Some national missions are associated with institutions, but they are ad hoc, not designed to co-benefit, and there is a lack of coordination across sectors and institutions. The institutions that manage disasters are largely ignored, for example, those in water, energy, forestry, habitat planning, industry, and health. There is a contention that the design of an action plan and mission must take into account the considerable empirical and theoretical work of social scientists on institutions in the broad area of environmental governance in an extensive country, viz., India, with a federal configuration and the requirement for polycentric governance to address bottom-up and top-down constraints. Climate change-induced vulnerabilities are becoming increasingly relevant as state governments, district administrations, and regional development bodies prepare their action plans and strategies for addressing climate change.

While historical analysis can yield insightful information, a spatially specific assessment of climate change adaptation in modern times is also necessary. Adaptation will become increasingly crucial as the inevitable shocks of climate change unfold at the regional and local levels [10,27]. The Ministry of Environment and Forests (MOEF) was renamed the Ministry of Environment, Forests, and Climate Change (MOEFCC) in May 2014 after an administrative division was created in response to the rising significance of climate change regulation for India's newly formed government [28]. The national development program of India includes adaptation activities as a major component, which will provide further impetus to the country's efforts to adapt to climate change. Governments, however, are currently gradually interested in supporting, promoting, and learning from indigenous communities that are coping with climate change adaptation as part of building a comprehensive regulatory framework for climate change mitigation and adaptation from top to bottom [29–34]. Adaptation policy in India has evolved in tandem with the government's latest initiatives, such as 100 Smart Cities and Low Carbon Strategies for Inclusive Growth. The alignment of targets and primacies across countries sparked by strong political determination is critical to improving adaptation practices, as suggested by Conway and Mustelin [35].

Local institutions at the hamlet and village scale may require the assistance of higher-level institutions with technical, financial, or material resources to respond and act effectively, such as by helping farmers build, maintain, and operate irrigation sources. The formation of horizontal relationships becomes more important as higher-level institutions engage in more interactions and negotiations with one another at the national and international levels, though local institutions may use what Berkes refers to as social movement networks to gain influence and relevance at both levels [36].

2.2. Methods

Along with a qualitative research approach, the current study makes use of secondary data and information. This research review highlights the shortcomings of various policies and institutions while also examining them. A rigorous process for reviewing and evaluating papers involves looking through a variety of materials, including news articles, academic journals, institutional reports, and reports in print and digital media. An overview of the condition of climate change in India was carried out using secondary literature and official publications on the subject's future projections.

3. Results and discussion

3.1. Climate change trend and state of affairs

India experiences significant climatic fluctuations and a diverse array of agroecological zones due to its geographical placement and topography, making it a highly climate-sensitive country on Earth. The Indian monsoon, which corresponds to periodically reversing open-ocean currents that circulate between the Bay of Bengal and the Arabian Sea, greatly influences the climatic situation of the subcontinent [37]. India experiences more than 85% of its annual precipitation during the monsoon season, making agriculture and water availability vital. A recent study suggests an association between the El Nino-Southern Oscillation pattern and the Indian summer monsoon, with ENSO events driving monsoon variability [38]. The Indian monsoon is capricious since there have been several instances of both excessive and scant precipitation throughout its recorded history, causing both droughts and floods [39].

The climate of India has undergone numerous variations over the preceding few decades. The average temperature of the country has risen by about 0.2 ℃ each decade from 1971 to 2007. Temperature anomalies have been severely affected by ENSO events during specific seasons. Observed variations in rainfall patterns are quite varied throughout the country, and there is a growing tendency for extreme rainfall to occur on a single day in several parts of India. There have been significant variations between the monsoon season's extremes of dryness and wetness over a period between 1951 and 2011 [40].

Water availability in India is predicted to drop from 1820 m^3 per capita in 2001 to 1140 m^3 by 2050, which could potentially lead to a grave water crisis. During the winter months, the expected drop in precipitation may result in decreased water storage and increased water stress. Fewer rainy days and higher rainfall intensities are also anticipated; this is likely to adversely influence groundwater recharge potential due to the high runoff and flooding risk [41]. Additionally, coastal regions are anticipated to witness an increase in loss and damage to human life and property due to an increase in cyclone strength [41]. All Indian river basins except Narmada and Tapti are expected to have a reduction in run-off, while the Sabarmati and Luni river basins are expected to witness a decline of more than two-thirds [13]. Salinity ingress triggered by rising sea levels as a direct consequence of climate change would pose a growing hazard to India's water supplies, especially along the coastal zones [41].

Several crops may benefit from an increase in carbon dioxide, but a corresponding rise in temperature and rainfall variations would significantly impact food supplies. According to the AR-5 of the IPCC (IPCC 2014), crop production is expected to decrease by 10%–40% by 2080–2100. The NICRA reports that every 1 ℃ rise in temperature will lead to the loss of 4 to 5 million tons of wheat production [42]. Climate change is expected to exacerbate heat strain in dairy animals in the future, which will harm their ability to produce and reproduce [43,44]. Rising sea and river water temperatures are expected to disturb fish spawning, migration, and harvesting [45–47]. The Indian coastline, which stretches for ~7517 km, is at risk of climate change impacts such as coastal salinity, water intrusion, varied sediment fluxes, littoral erosion, and sea level rise. A rise of 1 ℃ could significantly affect the survival and distribution of diverse freshwater and marine fish species. The country has experienced an increase in extreme weather events in some parts or other parts mostly every year in the previous decade, viz., floods, droughts, cyclones, hailstorms, heat waves, and cold waves. The augmented number of mid-season droughts and heavy showers has led to soil depletion, water crises, decreased food production, instability, and poor livelihoods for farmers in the country. Changes in temperature and rainfall could impact cereal, fruit, aromatic, and medicinal plant quality significantly. There have been recent outbreaks of whiteflies and pink bollworms on cotton in northwest India due to abnormal weather patterns.

The Climate Risk Index-2021, published by Germanwatch India is 7th out of 181 countries considered to be at "extreme risk" of climate change [48]. Maplecroft's Report highlights possible adverse effects of climate change in India and other highly susceptible countries on poverty, height, food production, migratory patterns, and social stability [49]. Six life-supporting sectors are considered in the ND-GAIN measures of overall vulnerability: food, health, human habitat, infrastructure, ecosystem services, and water. The vulnerability score highlights which countries are most susceptible to climate disruptions. The ND-GAIN Country Index of Readiness Measures determines where their climate resilience is lacking the most and has the greatest capacity to adapt [50]. **Table 1** presents other indices that highlight India's climate risk context.

Table 1. India's ranking on different climate risk indices.

Index	Rank/score	Source
ND-GAIN Country Index, Vulnerability Measures–2023	138 (with 0.498 score)	Chen et al. [50]
ND-GAIN Country Index, Readiness Measures–2023	104 (with 0.389 score)	Chen et al. [50]
Climate Risk Index (CRI)–2021	7 (among the 10 most affected countries)	Eckstein et al. [48]
Climate Change Performance Index (CCPI)–2024	7 (among the top 10 countries in terms of climate protection and country's accomplishments)	Burck et al. [51]
Women's Resilience Index (in South Asia)	42.2 (out of 100)	The Economist [52]
One of the top five countries by number of people affected by natural disasters in 2013	16.7 million	OCHA [53]

3.2. Critical assessment of climate change adaptation policies in the agriculture and fisheries sector

Indian agriculture is expected to double by 2020, according to the Agricultural Policy Vision 2020. Although it has become clear that climate change has a profound impact on India's agricultural output, the strategy makes no mention of it as a possible concern. Despite this, the report acknowledges the persisting and emerging concerns related to water shortages and resource degradation in agriculture. The vision statement goes on to stress the importance of technology-driven agricultural growth and the availability of dry-land technologies. The National Policy for Farmers [54], a previous report intended to make farming more economically viable, acknowledges the adverse effects of climate change.The potential of agroforestry to function as an invaluable instrument for enhancing farmers' and rural residents' resilience towards the effects of climate change is acknowledged in the National Agroforestry Policy [55]. The strategy focuses on reducing the risk associated with extreme weather events. Subsidies for agroforestry adoption and sustainable agroforestry for renewable biomass-based energy make up two of the specific measures described in the strategy. Public-private partnerships, agroforestry, contract agriculture, and special-purpose vehicles could be explored for the advancement and development of agroforestry.

Climate change is a major concern for India as it strives to ensure the security of food and nutrition for its growing population. It is essential to conduct rigorous research on this important topic to address the challenges associated with maintaining food production in an inconsistent climate and to formulate strategies for agriculture adaptation and mitigation to participate in international forums such as the UNFCCC.

The direct impact of climate change on fish production and livelihoods may be compounded by indirect effects arising from the adaptive strategies followed by different sectors. Impact predictions are very challenging and uncertain because of these possible interactions. Adaptive strategies that emphasize flood control, drainage, and irrigation schemes may be necessary as precipitation patterns change and extreme flooding events increase in agricultural sectors. Fisheries may be adversely impacted by the loss or degradation of crucial coastal habitats in coastal areas due to potential declines in mangrove forest habitat brought on by sea level rise, alterations in sediment and pollutants interleaved from river and lake basins, brackish intrusion and littoral erosion, land reclamation for agriculture, or overexploitation [56]. For instance, the loss of mangrove forests may negatively impact the assortment of benthic invertebrates like tiger prawns and mud crabs, which, according to Ellison [57], are improperly used or controlled for profits exceeding US $4 billion annually.

Climate change adaptation entails creating a series of actions that will enhance performance when faced with changing backdrops brought on by climate change. The majority of rural communities heavily count on farming for their livelihoods and income, so adapting to climate change in agriculture is crucial for advancing their livelihoods and safeguarding food security. Stress adaptation techniques include plant breeding, pest control methods, seed delivery systems, etc., and mitigation focuses on reducing agricultural greenhouse gas (GHG) emissions. Agriculture has a dual impact on GHG emissions; first, it is a major source of GHG emissions, and second, it has enormous potential to slow down climate change. The agriculture sector produces over

one-third of greenhouse gas emissions, mostly in the form of CH_4 and N_2O, which are released from fertilized soils, biomass burning, enteric fermentation, paddy cultivation, manure production, and application. Crop production also offers a chance to slow down global warming in two different ways: by stowing carbon and by lowering GHG emissions. India's GHG emissions have grown significantly in recent decades because of its rapidly expanding economy and population. The electric power sector in India emits a significant amount of greenhouse gas emissions from coal-fired power plants, which emit large quantities of carbon dioxide. Rice paddy farming is also one of the second-biggest contributors to methane emissions. The economic expansion of India has resulted in it being the third largest producer of greenhouse gases (GHGs) in the world, behind the United States and China. However, India's per-capita GHG emissions—which stand at 2.8 tCO_2e—are significantly lower than the global average [58].

3.3. Institutional arrangement for climate change adaptation

To facilitate its efforts to take action on climate change, the Government of India has established an inclusive institutional setup addressing this concern (**Figure 1**). The highest-level advisory council in this framework, chaired by India's Prime Minister, is the Prime Minister's Council on Climate Change. Climate change adaptation planning and policy are coordinated by MOEFCC, the national nodal agency. The Ministry of External Affairs is accountable for international climate negotiations and other procedures, such as negotiations under the UNFCCC.

This NAPCC and its constituent missions emphasize formulating strategies for climate change action at regional and local levels that address the several agroecological environments and socio-economic circumstances prevailing in their respective regions. The National Adaptation Fund for Climate Change (NAFCC) was created in August 2014 to cover the costs associated with climate change adaptation for the Indian States and Union Territories that are most susceptible to its adverse consequences.

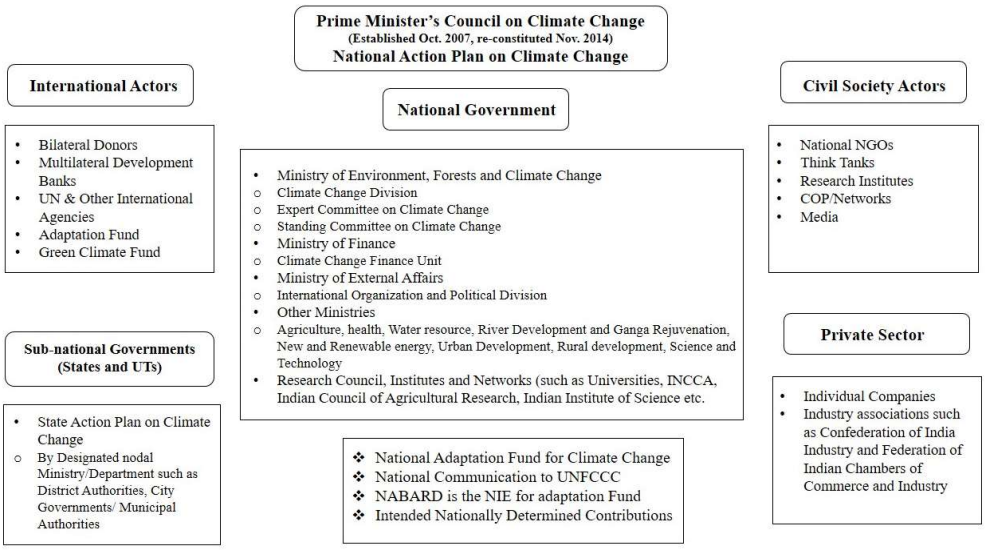

Figure 1. Institutional arrangement for climate change adaptation policy planning and implementation in India.

The government set up a budget allocation of 16.67 million US dollars under the federation budget in 2015. Moreover, the government has proposed establishing a National Centre for Himalayan Studies in Uttarakhand to conduct cutting-edge scientific research in the vulnerable and climate-sensitive Himalayas on topics related to climate change adaptation.

Projects under the NAFCC prioritize climate resilience needs in the spaces designated under the SAPCC (State Action Plan on Climate Change) and pertinent missions under the NAPCC (National Action Plan on Climate Change). Both NAPCC and SAPCC advocate active participation of local establishments, i.e., Panchayati Raj Institutions and Gram Sabhas at the village and hamlet level, Village Councils, Water Users' Associations, JFM/CFM/FRA Committees, Urban Local Bodies, and Van Panchayats, to combat climate change. Additionally, they mention how local communities should leverage their indigenous ecological knowledge and value systems to address climate change. In contrast, there are numerous high-powered committees, directed by state and national ministers, as well as advisory committees consisting of scientific boards and senior bureaucrats, as well as the NMSHE, which envisages some sort of regional institutional framework for the Himalayan counties. NABARD has been nominated by the government as the National Implementing Entity (NIE) for carrying out adaptation endeavors under NAFCC due to the existing arrangement with it as the National Implementing Entity (NIE) for the Adaptation Fund (AF) under the Kyoto Protocol and its existence throughout the nation. Under the terms of the agreement, NABARD would play a role in facilitating the identification of project concepts and proposals from the State Action Plan for Climate Change (SAPCC), project design, review, and approval, fund disbursement, evaluation and monitoring, and stakeholder capacity building, together with state governments.

Climate action in India is currently being pursued using a co-benefit approach, which considers both development objectives and climate change mitigation outcomes. They have initiated several plans and policies in line with this approach [22]. There are indications that national- and state-level action plans will face challenges in conception and implementation. The Government of India has initiated several plans and policy development processes adhering to this approach [22]. Preliminary indications show that state- and national-level action plans will have substantial conceptual and implementation challenges. In addition to addressing issues of financing, various activities where the jurisdictions of the state, central governments, and local establishments overlay will likely pose difficulties when they are implemented. One of the greatest challenges would be to link development actions with climate issues. As Dubash succinctly put it, "Climate change will have to be integrated as an objective within an already littered institutional landscape" [22].

3.3.1. Infrastructures for climate-smart agriculture (CSA) research and extension

For the first time in Asia, we have constructed some special facilities as part of the NICRA project. The establishment of high-quantity plant phenomics facilities at four ICAR constituent institutes would make it easier to screen a substantial amount of germplasm for various characteristics. Numerous genetic resources were gathered

for the target crops, including rice, wheat, chickpea, maize, tomato, pigeon pea, green gram, black gram, and mango, and phenotyping work is currently being done at various partner institutes to characterize the germplasm. The most promising genotypes to improve hybrids and new varieties that can withstand climatic stress, i.e., drought, heat, flooding, etc. The hazards may be logistical, physical, technological, or regulatory, as a result of climate change, putting infrastructure growth at risk [59,60]. Natural resource-dependent infrastructure, such as hydroelectric facilities in the Himalayas, is more susceptible to flooding, landslides, and cloudbursts. Cyclones and fluctuations in sea level pose an additional risk to coastal infrastructure, including telephones, roads, power transmission, railroads, and medical centres [60].

Using the CO_2 Temperature Gradient Chambers (CTGC), Temperature Gradient Tunnels (TGT), Free Air Temperature Enrichment Facility (FATE), and Free Air CO_2 Enrichment Facility (FACE), it clearly shows how various crops respond to high temperatures and carbon dioxide. To examine the impact of several environmental factors, including humidity, temperature, and air movement, on livestock, with a focus on cattle and buffaloes, psychometric chamber construction and operation were done. Studies conducted across the nation on the impact of temperature on mango flowering behaviour resulted in the creation of a spray composition and agro-methods to combat flower synchrony. The concerns of drought and flooding impacting tomatoes have been resolved through inter-specific grafting of tomatoes. For various stem combinations of tomato varieties or hybrids, location-specific brinjal rootstocks have been discovered. Scientists at network cooperating centres and Krishi Vigyan Kendras (KVKs) offered agromet advisory services (AAS) as a pilot initiative in 25 selected districts using block-level forecasts given by the Indian Meteorological Department (IMD).

3.3.2. Human resources for CSA technology

The process of adapting to a changing climate necessitates making decisions at crucial moments to respond, which can include adopting resilient technologies for crop and livestock husbandry that assist farmers in withstanding climatic extremes. Farmers need to understand coping mechanisms to overcome climate variability to embrace climate-resilient agricultural technologies. The NICRA project has been designed to encourage climate resilience through long-term adaptive farming by sustaining imperative resources, i.e., soil and water. Project objectives include enhancing the capacity of project functionaries, small farmers, and relevant stakeholders to cope with climate change and imparting climate resilience skills. These capacity-building initiatives are implemented on several levels. This makes it easier for farmers and other stakeholders to put information, tools, and best practices into effect. A cohesive approach to lay out capacity-building activities was implemented by 41 research strategic partners, 121 Farm Science Centres (KVKs), 11 Agricultural Technology Application Research Institutes (ATARIs), 23 All India Coordinated Research Project on Agro-Meteorology (AICRPAM)-NICRA centres, 25 All India Coordinated Research Project on Dryland Agriculture (AICRPDA)-NICRA centres, and 34 competitive and sponsored research projects across the country. This extensive network of NICRA-affiliated capacity-building institutions designed training courses

to meet the knowledge and skill requirements of project participants, hence improving capacities for efficient output delivery.

3.3.3. Best practices on climate change adaptation in agriculture technology

Assisting farmers to acclimatize to the current climate variability, the NICRA's Demonstration Component (TDC) will showcase practices and technologies that are peculiar to a specific location. To boost their potential for adaptation and resilience to climate change, the climatically susceptible districts are implementing location-specific technology for crop production, livestock management, and fisheries management. In 151 of the most susceptible districts around the country designated through KVKs, technologies with the potential for coping with climate variability are being investigated under TDC. The Institutional Intervention Component of NICRA strives to create an enabling support system in villages consisting of strengthening existing institutions or establishing different ones (Village Climate Risk Management Committee (VCRMC)), administration and establishment of Custom Hiring Centres (CHCs) for farm equipment, seeds, and fodder storage, formation of commodity groups and water-sharing establishments, setting up of community nurseries, and beginning of collective marketing via leveraging value chains. The NICRA initiative established 100 CHCs for farm equipment, which are managed by VCRMC, which is supervised by villagers. For the creation of locally pertinent content and its transmission in text and voice-enabled formats, modules on the utilization of information and communications technology (ICT) for knowledge empowerment in communities regarding climate risk management are also being scheduled in certain KVKs. A total of 128 KVKs/farm science centres connected to NICRA projects have also undertaken initiatives like village-level participatory seed fabrication of flood- and drought-tolerant varieties, short-duration, establishing the seed banks featuring these varieties, establishing the fodder bank and demonstration, and enriched varieties of fodder seeds in NICRA villages. An array of climate-resilient interventions (annual and perennial crops, irrigated rice, forestry, livestock, inputs, and land use change) were implemented in Gujarat and Rajasthan to reduce greenhouse gas emissions. The GHG emissions (CO_2, CH_4, and N_2O) in seven villages were then converted into an analogous quantity (tonne CO_2 equivalent), which was negative, suggesting a reduction in greenhouse gas emissions.

3.4. Overlap and gap in agriculture and fishery sector policies

To handle and run these facilities, manpower (scientists, research assistants, research associates, technical officers, etc.) has received training. Crop improvement for different difficulties necessitates years of study and experimentation in various locations. The project's efforts contributed to the creation of hybrids and cultivars suitable for commercial cultivation. Others are in various phases of development and may take a few more years to be issued as varieties, hybrids, or new breeds. The development of simulation models to evaluate the impacts of climate change at the regional level is still in its early stages. Data collection from various sources and the standardization of basic data sets have led to good progress. These data sets will be utilized for modeling during the following stage. The goal of the research, which is mostly long-term in nature, should be to continuedata sets will be utilized for modeling

during the following stage. further to accomplish the anticipated outcomes and outputs.

Facilitate the participation of agriculture sector representatives in national adaptation planning by clarifying mandates and engaging focal points for each sector. Assess the vulnerability and risk of agriculture, as well as existing knowledge, approaches, plans, strategies, investment frameworks, and potential institutional gaps. Assessment of and identification of associations between adaptation needs and agriculture development goals is also required to address gaps and weaknesses in agriculture adaptation planning.

Local institutions at the hamlet and village scale may require the assistance of higher-level institutions with technical, financial, or material resources to respond and act effectively, such as by helping farmers build, maintain, and operate irrigation sources. Higher-level institutions are increasingly involved in interactions and negotiations with each other at national and international scales; hence, the establishment of horizontal linkages becomes more significant, although local institutions might seek relevance and clout at both levels through what Berkes calls Social Movement Networks [36].

4. Conclusion and recommendations

India is adapting its approaches to assess climate change sensitivity according to the increasing vulnerability of several ecosystems and economic sectors that support human survival to climate-related hazards. Stress and tremors brought on by climate change are having a detrimental effect on water resources, forests, and agriculture, which are critical to the existence of millions of people. Rural-urban mobility, the feminization of agriculture, and shifting socioeconomic conditions are contributing to poverty, susceptibility, and marginalization in the country. In several regions of India, extreme weather events associated with climate change, like heat waves, heavy precipitation, and cloudbursts, are becoming more frequent [4]. Furthermore, climate change adaptation studies and on-the-ground projects in India have highlighted the susceptibility of the nation as well as the capacity of different stakeholders and other institutional opportunities for implementing adaptation efficiently at different levels by highlighting the vulnerability.

The consequences of climate change exacerbate governance issues within a developing nation like India. India created the NAPCC in 2008 and has been proactive in defining its priorities for climate change. This action plan addresses both the mitigation and adaptation needs of the nation through eight missions. Adaptation-related issues are gaining momentum in policy planning and public discourse in India as a result of the recent wave of policy initiatives and institutional restructuring.

Farming and food systems have been adversely impacted by climate change, especially for smallholder farmers in the least developed and developing countries in terms of food and nutrition security. The adoption of climate-smart agriculture in South Asia resulted in the assessment and investigation of climate change trends in India, adaptation and mitigation strategies, and solutions. This study depends on an overview of the literature and secondary data. The findings suggested that global warming is continuously worsening and having an impact on global temperature,

erratic precipitation, growing drought, typhoons, flash floods, cyclones, and sea level rise. Agriculture is adversely affected, which reduces the yields of fisheries, agricultural products, and livestock. The implementation of climate-smart agricultural technologies, such as research and development, adequate capacity building, early warning system establishment, farmers' incentive policies, farming insurance programs, and concerted efforts to combat climate change in India, may help to mitigate its negative effects. However, a major obstacle to the planning and execution of adaptation in India has been the country's inadequate financial resources, which leaves the majority of adaptation needs unfulfilled.

4.1. Approach to adaptation to climate change

A climate-resilient approach to development is a continuous process that combines adaptability, creativity, and collaborative solutions with effectiveness in reducing the effects of climate change and other forces influencing development. If the effects of climate change are severe enough to need consideration, this approach will probably necessitate taking transformative changes in threatened systems into account to sustain development without significant interruptions [61]. Various adaptation solutions are still required to be developed for various agricultural sub-sectors, for various geographical regions, and for farmers with various resource endowments. Accurate information and statistics on emissions, as well as strategies that might be utilized to decrease emissions, must be obtained under the country's obligations to decrease emissions. The nation's manufacturing sector will further reduce its carbon footprint by employing the methods mentioned under NICRA for the measurement of GHG emissions from various management activities. The results of the NICRA project are contributing to copious national project reports, including the Nationally Appropriate Mitigation Action (NAMAs), Biennial Update Report (BUR), National Mission on Sustainable Agriculture (NMSA), Intended Nationally Determined Contribution (INDC), and various other missions under the National Action Plan on Climate Change. It is crucial to understand climate change's systemic effects and its remedies in greater depth and aspect to decrease the emission intensity of the Indian economy by 32%–35% by 2030 [62,63]. To build multi-location, multi-sector mitigation, and adaptation plans, the efforts started under NICRA a few years ago should be continued and expanded in scope and content. This would help mankind address the major problem presented by climate change in agriculture.

4.2. Policy recommendation for improving institutional arrangements

Climate change must be mainstreamed and integrated into important national socio-economic and environmental sectors, along with reducing climate risks to people, ecosystems, and built environments, while restoring and protecting natural resources wisely. The following policy should be adopted immediately to counter climate change's impact on agriculture and fisheries:

1) A climate-smart agriculture strategy is the most effective way of dealing with extreme weather events and hazards associated with climate change in agriculture. Considering climate change induced by multi-faceted factors, policies aimed at promoting climate-smart agriculture and reducing its effects would need to be based

on an explicit understanding of its suitability, costs, and benefits as well as its environmental impact [64,65].

2) It is imperative to prioritize policies that promote adaptation practices, increase carbon sequestration, and decrease greenhouse gas emissions. Organic farming can reduce greenhouse gas emissions.

3) Appropriate fertilizer application can reduce nitrous oxide emissions; systematic livestock management with high-yielding breeds can reduce livestock emissions; and a scientific rice cultivation approach can reduce methane gas emissions.

4) The other policy recommendation is to introduce a minimum support price (MSP) for agricultural produce so that farmers can get good prices for their produce. Small farmers are bound to sell their produce to local businessmen at low prices.

5) The government should initiate a local-level soil suitability map for different crops and offer training programmes for better agriculture production.

6) A crop insurance policy will be beneficial for the farmers. The government has already introduced a crop insurance scheme, but farmers are not getting the benefits of this programme.

7) Wild animals are destroying crops in most of India. Therefore, it is suggested that the government should prepare a suitable plan to protect crops from wild animals.

8) The ability of society to respond to climate change is largely dependent on effective local institutions. Adapting to the impacts of climate change is highly dependent on a wide range of factors that are shaped by complex institutional arrangements; effective local institutions are key. Numerous factors influence our ability to adapt, including production strategies, household dynamics, social support systems, water and land governance, weather and climate information, and interactions with external influencers.

Moreover, since transparency, democracy, and inclusiveness are the utmost requirements, the interaction between local and national institutions is important but often complex. Climate change challenges pose a challenge for such institutions, and national institutions must create environments that enable local institutions to be both materially and socially effective.

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